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DEACON LABORATORY**

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**Routine spectral wave data acquisition  
on OWS *Cumulus***

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# DOCUMENT DATA SHEET

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<b>ABSTRACT</b>  <p>A number of research and survey vessels are fitted with shipborne wave records (SBWRs) which operate reliably with minimal servicing. In the past, the wave data have normally been logged as a time series, using central ship's computing facilities, or recorded by a simple chart recorder. This resulted in unacceptable post-processing delays and costs.</p> <p>This document describes an automatic logging/processing system which was installed and operated successfully for a number of years on OWS <i>Cumulus</i>, requiring manual intervention only at monthly intervals to download the processed data files. The system uses a dedicated personal computer, with analogue input card, to acquire and spectrally analyse the wave amplitude signal and to save the spectral data on hard disk.</p> <p>The document fully describes the hardware, software and operational requirements of the system.</p>	
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<div style="display: flex; justify-content: space-between;"> <span>Copies of this report are available from: <i>The Library</i>,</span> <span>PRICE      £0.00</span> </div>	

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## **ROUTINE SPECTRAL WAVE DATA ACQUISITION ON THE O.W.S. CUMULUS**

### **1. Background**

Measurements of surface wave spectra were required for use in conjunction with data acquired by the Fast Sampling Wind Sensor system installed on O.W.S. Cumulus for estimation of surface stress. This was necessary to test theories on the relationship between the degree of development of the wave spectrum and the surface friction.

A Mk 3 shipborne wave recorder (SBWR) was already in existence on O.W.S. Cumulus as a result of a previous commission for wave climate research. However, the data acquisition procedure used previously was not ideally suited to the new requirements. Consequently, use was made of experience gained with commercial data logging software, acquired for use in an early version of the Fast Sampling system, to develop a simple acquisition system in very short time.

### **2. Instrumentation**

A standard Mk 3 SBWR was already installed on the ship; this incorporated the higher quality accelerometers and pressure sensors specified at the last design update by the Institute of Oceanographic Sciences, Taunton. The method of operation of the SBWR is well known; the basic principles were published by Tucker (1956). More recently, Pitt (1988) has extended work done by Crisp (1987) on the correction of the sensor output for the response of the ship in which it is installed. This work resulted in a spectral correction factor based on a nondimensional frequency parameter, calculated from the wave frequency, the length of the ship and the depth of the pressure sensors below mean water level. In addition to this correction, it is necessary to correct for the response of the electronics unit. This includes matching high pass filters in the double integrators used to convert heave acceleration to displacement and in the pressure signal channel. These corrections are given in Appendix A.

The SBWR output can be recorded in analogue form on a built-in pen recorder, as a backup to the digital system described below, and to provide a quick confirmation of correct operation. For example, very low frequency oscillations in the record generally indicate accelerometer instability or non-linearity. In particular, monthly analogue test records are made of the individual sensor outputs; these are checked by the procedure described in Appendix B, below.

A second analogue output from the SBWR, with the nominal scaling of  $1/15^{\text{th}}$  volt per metre, is logged by the PC-based system described below. For the purpose of spectral analysis, it is normal to analyse sections of wave data, sampled at a rate of 2 Hz, with a duration of 10 to 20 minutes. This sampling rate is high enough to prevent aliasing of spectral energy. The record length and the resulting number of samples give adequately narrow confidence limits in the spectral estimates whilst allowing the monitoring of significant changes in the wave spectrum with time.

For these studies, it was decided to record wave spectra at intervals of 20 minutes. This allowed a total record duration of 1024 seconds (the number of samples being a power of 2 for convenience in the Fast Fourier Transform analysis). Since trouble had been experienced previously with electrical interference arising from the routine weather reporting radio transmissions on this ship, it was decided to split the record for analysis into two separate sections, each of 512 seconds (1024 samples), and to record the two resulting spectra in separate files. It was considered unlikely that the radio transmissions would degrade both sections.

### **3. Data Acquisition/Processing Hardware (Shipborne)**

The analogue output from the SBWR had to be converted to digital form, with a sampling rate of 2 Hz. A resolution of 12 binary bits was considered adequate to cover the nominal full scale wave height range of  $\pm 15$  metres ( $\pm 1$  volt). The decision to use previously tried and tested hardware and logging software resulted in the use of an N.E.C. APC-H7020 *Powermate* (trademark of N.E.C.) Portable PC-Compatible computer, fitted with a Strawberry Tree ACPC-12-16 analogue input card and LabTech Notebook software.

The N.E.C. machine incorporates a 286 processor, running at 10 MHz, with 640 KB RAM, an LCD display with 640 x 400 dot resolution, a 720 KB  $3\frac{1}{2}$ -inch floppy disk drive and a 40 MB hard disk drive. It has 2 full sized (AT) slots available for installation of the ACPC-12-16 and an Everex Tape Streamer card for backup purposes. An 80287 maths co-processor was installed to speed up the spectral analysis.

The ACPC-12-16 card incorporates a 12 bit Analogue to Digital convertor. Up to 16 differential analogue inputs can be selected by software although only one is required for the present application. The input voltage range (for bipolar inputs) can be selected by software to be one of the three options  $\pm 25$  mV,  $\pm 250$  mV and  $\pm 5$  V full scale. The worst case equivalent resolution will therefore be  $15 \times 5/2048$  metre, or 3.66 cm. In the present application, the card is set by software to autorange for best resolution. In single channel operation, the card takes a reading and transfers it to memory in 400  $\mu$ S (this includes range-changing time). The differential inputs and  $\pm 12$  volt power supplies on the card are connected via ribbon cable to a terminal panel, type T41, in terminal box, type B10. This box facilitates connection to the "outside world" and allows incorporation of a simple anti-aliasing input filter.

### **4. Data Acquisition/Processing Software (Shipborne)**

The software used comprises an in-house GWBASIC control program called SBWRCHC.BAS\*, the LabTech Notebook software and the Strawberry Tree software. The acquisition and processing is largely achieved by use of the LTN software, which is called from the control program, as shown by the flow diagram, figure 1 below.

---

\* A second version of this program, SBWR690.BAS, was written for use where only printer output of Hs and Tz was required, i.e. the spectra are not written to disk.

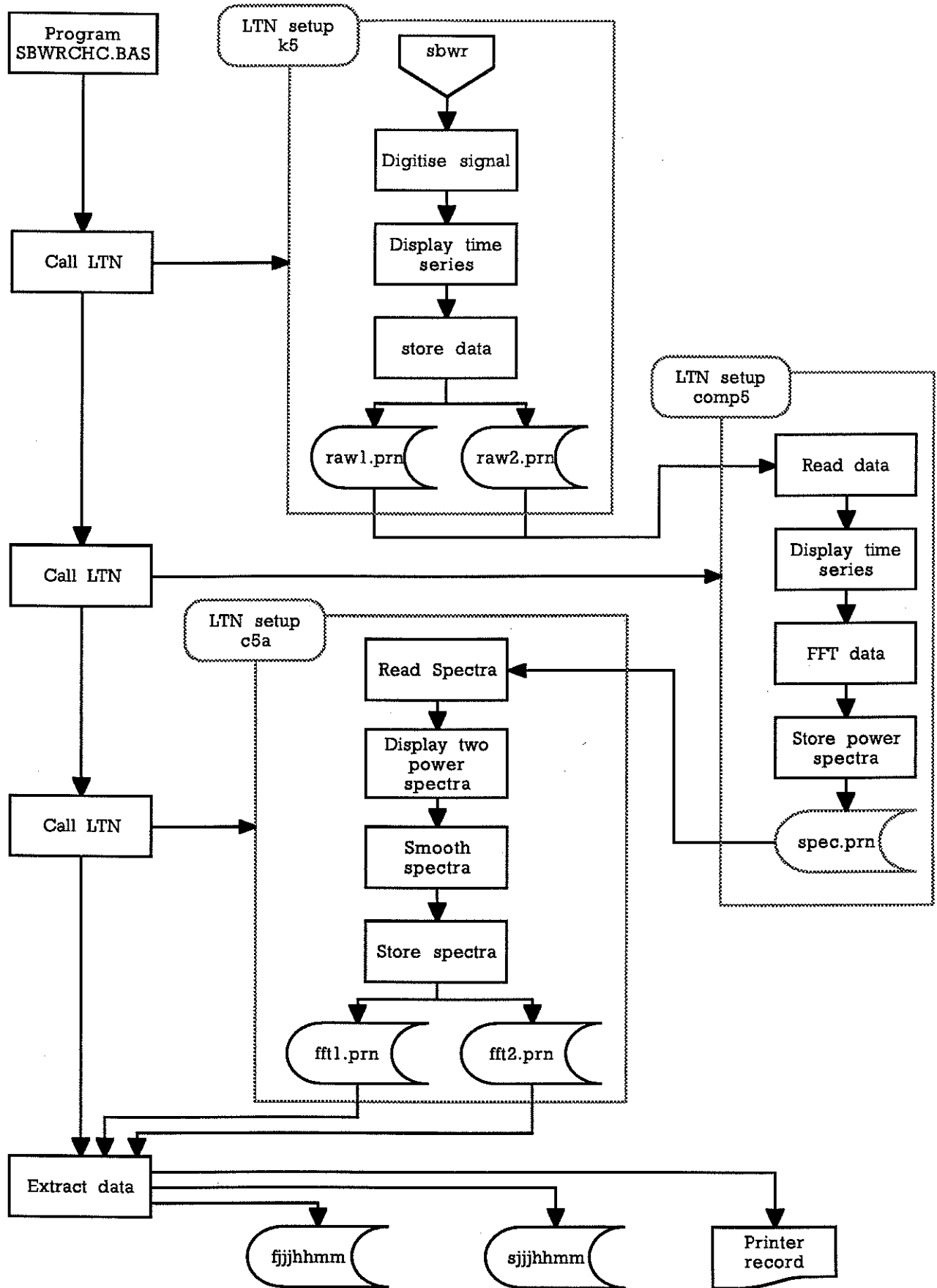


Figure 1 Flow diagram for the SBWR logging system

The Strawberry Tree ACPC card is supplied with driver software, which is installed by the command `ADrive` upon boot-up. The program `FIND` must also be executed upon boot-up to check out and calibrate the card. In order that these programs are run upon power-up, the `AUTOEXEC.BAT` file includes the commands:

```
c:\nbsbwr\adrive
```

```
c:\nbsbwr\find -d -c
```

The LabTech Notebook (LTN) software can then access the ACPC correctly. The programs `ADrive.COM` and `FIND.EXE` are held in the `c:\nbsbwr` directory, together with a number of other files including the calibration file `CALIB.DAT`. An overall summary of the directory structure is shown in figure 2, below.

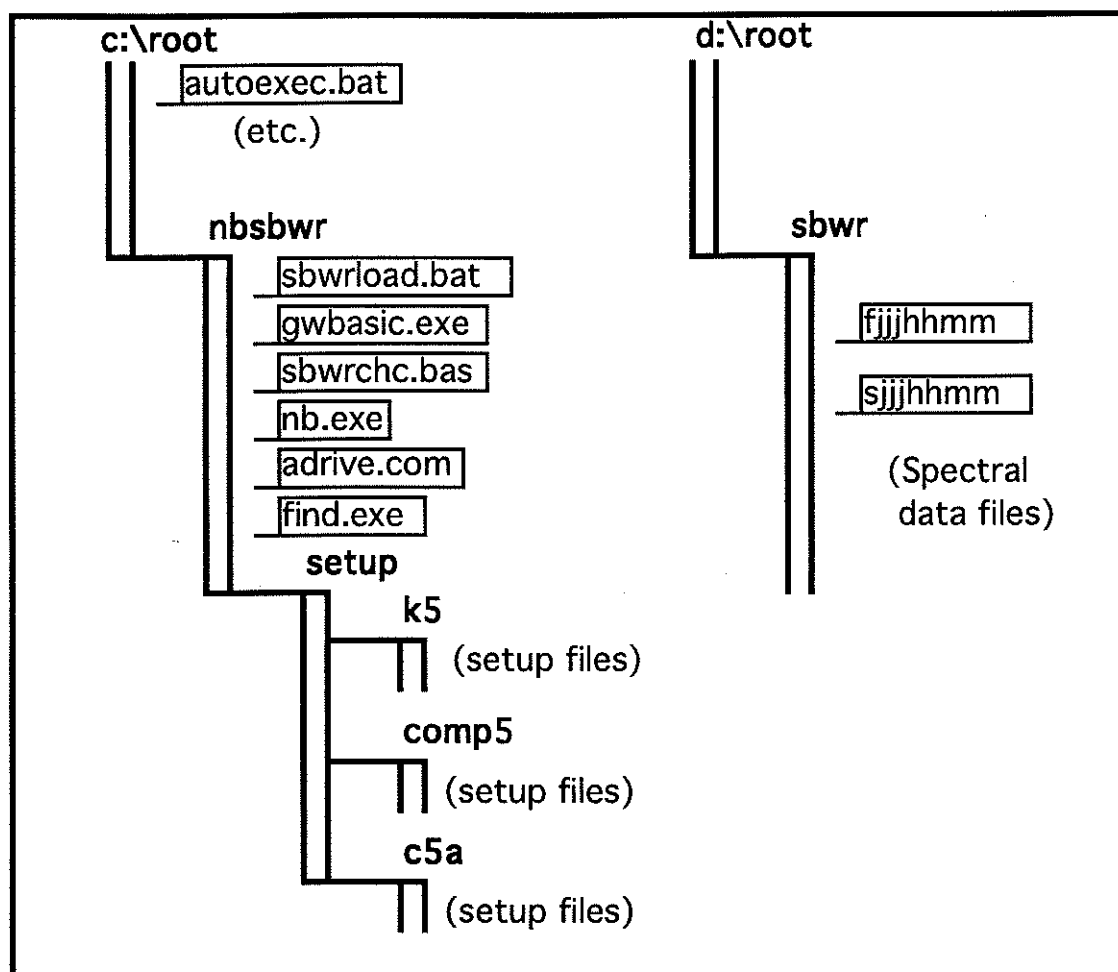


Figure 2 Directory Structure (abbreviated)

A detailed explanation of the LTN software will be found in the manufacturer's handbook but the following information should allow the user to find his/her way around. Note that changes should not be made to the setups without good reason!

The LTN software consists of a set of (manufacturer-supplied) program files, together with a number of user-created application-specific "setup" files. The latter files are created



after the user has specified the logging/processing procedures to be followed by LTN. The files for each setup are located in a separate subdirectory of the c:\nb\setup directory.

Three setups are used in the SBWR processing, as shown in figure 1; these are, somewhat arbitrarily and cryptically, named

k5  
comp5  
c5a

The setups are consecutively loaded and executed by shell "copy setup\setupname" and shell "go" commands from the GWBasic control program SBWRCHC.BAS or SBWR690.BAS (described below). The setups have the following functions:

#### 4.1 LTN Setup k5

This controls:

- the digitisation of the analogue signal from the SBWR
- the graphical display of the data in the form of two time series
- the storage of the raw sampled data in two ASCII files, raw1.prn and raw2.prn

Figures 3-8 (in Appendix C) show copies of the setup screens for k5. As will be seen, there are separate

<b>NORMAL DATA ACQUISITION/CONTROL SETUP</b>
--

screens for the two "Channels" 1 and 2, which correspond to the specifications for the 2 Hz digitisation over the two 512 second sections (channel 1 for the first section, channel 2 for the second section).

There are separate

<b>FILES SETUP</b>
--------------------

screens for the two output files 1 and 2, named raw1.prn and raw2.prn. There is one

<b>WINDOW SETUP</b>
---------------------

screen for the two display "windows", which sets the annotation of the axes and the length of the time axes. Finally, there is one

<b>TRACE SETUP</b>
--------------------

screen for the display "traces", which sets the vertical axis scalings and the type of line plotted.

Details of the procedures for inspecting and editing the k5 setup are given in Appendix C.

#### 4.2 LTN Setup comp5

This setup controls:

- the "replay" of the data, previously saved in files raw1.prn and raw2.prn by setup k5.
- the graphical display of the replayed data in the form of two time series
- the spectral analysis of each section of data, using the LTN FFT routine
- the storage of the power spectra in the ASCII file spec.prn

Figures 9-15 (in Appendix D) show copies of the setup screens for comp5. As will be seen, there are separate

#### NORMAL DATA ACQUISITION/CONTROL SETUP

screens for the four "Channels" 1 to 4. These correspond to the specifications for the replay of the two 512 second time series sections (channel 1 for the first section, channel 2 for the second section) and the execution of FFT routine on the two sections (channel 3 for the FFT of the first section, channel 4 for the FFT of the second section). There is one

#### FILES SETUP

screen for the output file spec.prn.

There is one

#### WINDOW SETUP

screen for the two display "windows", which sets the annotation of the axes and the length of the time axes. Finally, there is one

#### TRACE SETUP

screen for the display "traces", which sets the vertical axis scalings and the type of line plotted.

Details of the procedures for inspecting and editing the setup comp5 are given in Appendix D.

#### 4.3 LTN Setup c5a

This setup controls:

- the replay of the two power spectra from the file spec.prn
- the display of the two power spectra
- the smoothing of the spectra using the LTN Moving Av(erage) function
- the storage of the smoothed power spectra in the ASCII files fft1.prn and fft2.prn

Figures 16-23 (in Appendix E) show copies of the setup screens for c5a. As will be seen, there are separate

#### NORMAL DATA ACQUISITION/CONTROL SETUP

screens for the four "Channels" 1 to 4. These correspond to the specifications for the replay of the two power spectra from file spec.prn (channel 1 for the spectrum of the first section, channel 2 for the spectrum of the second section) and the execution of a Moving Average routine on the two sections (channel 3 for the moving average of the first section, channel 4 for the moving average of the second section). There are two

#### FILES SETUP

screens for the output files fft1.prn and fft2.prn.

There is one

#### WINDOW SETUP

screen for the two display "windows", which sets the annotation of the axes and the length of the time axes.

Finally, there is one

#### TRACE SETUP

screen for the display "traces", which sets the vertical axis scalings and the type of line plotted.

Details of the procedures for inspecting and editing the setup c5a are given in Appendix E.

#### 4.4 The GWBasic Control Programs SBWRCHC.BAS and SBWR690.BAS

These programs are listed in Appendix F and their contents are explained in Appendix G.

The control program SBWRCHC.BAS has 5 main functions; these are:

- to control the start of data acquisition (using the PC real time clock) at 20 minute intervals (03, 23 and 43 minutes past the hour)
- to control the sequence of processing using LTN
- to extract a reduced number of spectral estimates from the files fft1.prn and fft2.prn produced by LTN
- to save these in files fjjhhmm and sjjjhhmm, with time and date headers abstracted from the .prn file headers (jjjjhhmm are the Julian day, hour and minute at which the files are originally opened, each file contains 12 spectra)
- to output date/time + significant wave height to a printer

A version of this program SBWR690.BAS performs similar functions with the exception of creating the fjjhhmm and sjjjhhmm disk files.

Both versions have the ability to store up to six printer output messages in the event of a printer problem, until the printer is brought back on line.

The output files fjjhhmm and sjjjhhmm produced by SBWRCHC.BAS have nominal length 16573 bytes each and represent 4 hours of data. The volume of data per month (30 days) is, therefore, given by  $2 \times 16573 \times 6 \times 30 = 5966280$  bytes.

The GWBasic control program is run automatically upon power-up of the N.E.C. by including the following commands in the autoexec.bat file in the root directory:

```
cd nbsbwr
sbwrlload
```

The batch file sbwrlload.bat contains only one line which runs the control program,

```
gwbasic sbwrchc /f:4 /i
(or just gwbasic sbwr690, for that program)
```

The switches in the gwbasic sbwrchc command line allow 4 files to be opened simultaneously. In the case of sbwr690, only 2 files are opened simultaneously and 3 are allowed by default.

## 5. Operational Details

### 5.1 Manual Exit from Control Program

Note that, in the following instructions, ""enter *text*"" means type in the text *text* and then press Enter, whereas "press *K*" means press the key *K* without a following Enter. "Press *Shift-K*" means press the key *K* whilst holding down the Shift key.

The control program checks for any key presses at intervals during its operation. If it detects that the "right-hand-curly-bracket" key *Shift-}* has been pressed, the program aborts. The LabTech Notebook LTN.CNF configuration file is also set to abort on this key being pressed. If this file in the c:\nbsbwr directory is examined, the line

```
"DOS_KEY"="}"
```

should be present. Thus, if the machine is in the middle of running an LTN setup, one keypress of *Shift-}* will return to the GWBasic control program; a further keypress of *Shift-}* will abort the control program. The machine will then be running GWBASIC.EXE and to return to DOS, one must enter *system*

### 5.2 Downloading of Data

The data has to be downloaded onto 3 1/2" floppy disks, formatted for 720k. This is best done using the Directory Scanner program DS.

A detailed description of the steps necessary to achieve this is given below, for the sake of completeness.

At the DOS prompt C:\NBSBWR> (after exiting from GWBasic as above) enter *DS*; the program DS will then display the file tree and the contents of the C:\NBSBWR directory.

Change to the D: drive by pressing *D* and then entering *D* when the "Enter New Drive Letter" prompt appears. Then press the *F1* and *F2* keys (up and down, respectively) to move the highlight to the d:\sbwr directory. Press *Enter* to display the directory contents, i.e. the fjjjhhmm and sjjjhhmm files.

The files are nominally 16,573 bytes long, so that it should be possible to fit 43 on a 720k floppy disk. After a cruise there will normally be enough files to occupy 11 floppy disks. These can be transferred by:

- tagging batches of files with a total length of about 700k  
(pressing *T* with the -> and <- indicators either side of the files to be tagged)
- and then pressing *K* or *Alt-C*  
(depending upon which version of DS is installed)
- entering *a:* in response to the prompt  
"Enter Destination Pathname"

After each batch of files has been transferred, the prompt "Press any key to continue" will be displayed; press any key. The directory of the floppy should now be checked by:

- pressing *D* and then entering *a*  
(to change to the floppy root directory)
- inspecting the root directory to ensure all tagged files have been copied
- pressing *D* and then entering *d*  
(to return to the D:\SBWR directory)
- tag all the files just copied successfully and press *Alt-D* to delete them (this results in the prompt "Are You Sure? y/n [y]" where you should enter *y*)

Continue downloading to other floppies until all the files have been transferred and deleted from the d:\sbwr directory.

### 5.3 Correction of PC Real-Time-Clock

In the case of the NEC *Powermate Portable* with 286 processor, the real time clock is not affected by the DOS time and date commands.

In order to alter the RTC time or date it is necessary to use the NEC setup facility. Change to the setup directory by entering *cd c:\setup* from the DOS prompt and then enter *setup*. A menu will be displayed, the first (highlighted) choice being Initial Setup. Press *Enter* whereupon the System Parameters should be displayed. Press *Enter* again, whereupon TIME: is highlighted and then press *Enter* again, whereupon the message "Enter the current time (hh:mm)" is displayed. Enter the current time in GMT; this will then replace the old time in the System Parameters table. To change the date, press the grey cursor down key to highlight DATE: and press *Enter*. The message "Enter the current date (mm/dd/yyyy)" will be displayed. Enter the current date in the specified format; this will then replace the old

date in the table. Then use the cursor down key to highlight EXIT and press *Enter* three times; the machine will then reboot with the modified time/date.

## **6. Data Processing Software (Laboratory)**

### **6.1 SBWR Plots using DaDiSP Software**

DaDiSP ver 1 software is a commercially purchased Signal Analysis Software package, enabling digital signal processing using the principle of a graphics-based spreadsheet. This software normally accepts commands from the keyboard, but DaDiSP can also read instructions from a file, called a "Command File". For routine work such as displaying SBWR data to check data quality, command files have been developed to automate the process as much as possible. Programs have also been developed to convert the standard SBWR data files into the correct format, enabling them to be automatically imported into DaDiSP.

#### **6.1.1 System Requirements**

1) Personal Computer. An IBM-PC/XT/AT or compatible with at least 640K of RAM memory. One 360K floppy drive with a second floppy drive or hard disk.

2) Operating system. IBM PC-DOS 2.0 or higher.

3) Graphics Card. For basic resolution an IBM Colour Graphics Adapter (CGA) or compatible is sufficient. An Enhanced Graphics Adapter (EGA), Video Graphics Adapter (VGA), Hercules card or compatible adapter will provide much better resolution. Either a colour or black and white monitor may be used.

To enhance the performance of DaDiSP, it is recommended to use the 8087 math co-processor (or 80287 for PC-AT) to increase the speed of mathematical operations.

#### **6.1.2 Types of Plots Available**

For the SBWR there are three different types of plots available using command files, these are :-

1) Normalised plots

Energy spectra plotted against frequency from 0 to 1 Hz, with the energy scale automatically generated so that all plots fit the graph

## 2) Log plots

Log of the energy spectra plotted against frequency.

## 3) Fixed plots

Energy spectra plotted against frequency, where the energy scale is fixed, therefore some plots may go off scale

There is a DOS batch file for each type of plot, which resides in the C:\ root directory. This batch file assists the user by loading the correct files for each type of plot.

PLOT TYPE	BATCH FILE
NORMALISED	SBWRN.BAT
LOG	SBWRL.BAT
FIXED	SBWRF.BAT

Apart from the batch file there are four other files which have to be loaded or created, these are :-

1) The original data file e.g. "f3031326".

2) The GWBasic file which generates the Command file and produces the new data file.

SCONV.BAS

CLOG.BAS

CFIX.BAS

3) The Command file which loads the data into DaDiSP and generates the plot.

DCOM.DSP

4) The new data file.

SBWR.DSP

### 6.1.3 GWBasic Programs

The purpose of the GWBasic program is to convert the SBWR datafile into a file which can be imported into DaDiSP. This is achieved by sorting the SBWR dataset into 10 signals, each signal consisting of only the lowest 40 spectral estimates. Each signal is then given a name, generated from the time and date when the data was collected. This is then written to a new file called SBWR.DSP, along with a header which informs DaDiSP of the number of signals, number of data points and the signal names. The program also generates the Command File for the type of plot required and writes the list of instructions to the file DCOMP.DSP.

## 6.2 Operating Instructions

### 6.2.1 Creating SBWR Labbook

To use this system DaDiSP must first be installed on the PC and have a Labbook called SBWR created and saved by the software. This Labbook will be opened by the command file and the appropriate data loaded into it.

Install DaDiSP as per the manual and create a Labbook named SBWR, the procedure is as follows:

Change to the \DSP directory	
Enter <i>DSP</i>	To execute the DaDiSP software
press <i>C</i>	To create a new Labbook
Enter <i>SBWR</i>	Name of new Labbook
press <i>E</i>	Exit DaDiSP
press <i>Y</i>	Return to DOS

DaDiSP is now ready to be used to plot SBWR files by the use of Command files, the Labbook SBWR set loaded

### 6.2.2 Generating SBWR plots

DaDiSP and SBWR plotting software is currently installed in the Tandon PC (TAN 1), use this machine to generate the plots required.

Change to the Root directory and select the batch file for the required type of plot, this is usually SBWRN.BAT.

Either enter *sbwrn* or execute from DS.

You will now be asked by the program if the default for the data is drive C:\DATA , enter *n* if data is to be plotted from 720K 3.5" disks copied from the NEC.

It will now prompt you for which drive the data is on

enter *b* for the 3.5" floppy drive.

The program now displays all files stored on the specified drive, this helps the user to select the required file for plotting.

Enter in the file name e.g. *f3550903*

The program now sorts the data and then writes the command file and data file to disc, this takes a few seconds.

On exit from the basic program the batch file loads DaDiSP, specifying the command file name, you will see a number of different screens of the DaDiSP software on the screen as the instructions are automatically entered. DO NOT try and type any of the instructions from the keyboard. When the command file has finished loading in the data you will see 10 plots displayed and a prompt of PRESS F5 TO EXIT. At this point the plots can



be printed by using the *PRINT SCREEN* key on the PC. When this has been done press the *F5* key to exit DaDiSP, the command file now takes over again and exits DaDiSP in the correct fashion and deletes all the data from the DaDiSP worksheet. This returns the user back to DOS where the batch file is still active, it will then ask the user to EXIT to DOS by pressing *Ctrl-C*, or to CONTINUE by pressing any other key. If data discs need to be changed, then this point is a good time to do so, before further disc access is required.

### 6.2.3 Procedure for Short SBWR Records

When an SBWR record is incomplete, that is less than four hours of data, there will not be the full number of records in the file. When short records are processed the basic program will stop, displaying an error message (input past end). This means that the program has come to an END OF FILE MARK when trying to read in the full set of data.

At this point the user can either process a different file or process the short record by making some alterations to the basic program.

Entering *RUN* on a clear line, will re-activate the basic program and the user can continue by re-entering a new filename to be processed.

Alternatively the user can modify the basic program, if at this point the variable *I* is determined by entering the command *PRINT I*. This variable enables the number of records and the number of data points in the file to be determined. "*I*" gives the number of data points plus one in the file, therefore by subtracting one and dividing by 104 (data points per record) this gives the number of records in the file. Now list the program line 180 by entering *LIST 180* and change the value 1040 to the value of *I*, repeat for line 450. List line 240 and change the value 10 to the number of records calculated from *I*. Now re-run the basic program by entering *RUN* and re-enter the filename as before.

## 7. References

- CRISP, G.N. 1987 An experimental comparison of a shipborne wave recorder and a Waverider buoy conducted at the Channel light vessel  
Institute of Oceanographic Sciences Deacon Laboratory report no. 235
- PIIT, E.G. 1988 The application of empirically determined frequency response functions to SBWR data  
Institute of Oceanographic Sciences Deacon Laboratory report no. 259
- TUCKER, M.J. 1956 A shipborne wave recorder  
Transactions of the Royal Institute of Naval Architects, 98, 236-250

### Appendix A. Correction of the Data

The spectral density estimates  $P(p)$  and  $P1(p)$  written to the output files  $fjjhhmm$  and  $sjjjhhmm$ , respectively, are corrected for the Hanning data window loss but not for ship or electronics response. The  $p^{\text{th}}$  estimate,  $P(p)$  or  $P1(p)$ , is for a frequency  $f_p$ , given by:

$$f_p = \frac{5p-1}{512} \text{ Hz}$$

and the spectral width for each estimate is  $5/512$  Hz.

Each estimate should be corrected for the ship and electronics responses.

i.e.

$$P'(p) = P(p) \cdot S(f_p) \cdot E(f_p)$$

$$P1'(p) = P1(p) \cdot S(f_p) \cdot E(f_p)$$

where

$S(f_p)$  = Correction Factor for Ship Response

$$= \frac{1}{1 - A_0[1 - \exp(-A_1 \cdot a_4 + A_2 \cdot a_4^2 - A_3 \cdot a_4^3)]}$$

$$A_0 = 0.8103; A_1 = 0.5072; A_2 = 8.2; A_3 = 35.79$$

$$a_4 = f_p \cdot \sqrt{\frac{2\pi}{g}} \cdot \sqrt{ld} \quad (= \text{dimensionless frequency})$$

$$g = 9.81 \text{ m/s}^2$$

$l$  = waterline length of ship in metres

$d$  = depth of pressure sensors in metres

and

$E(f_p)$  = Correction Factor for Electronics Response

$$= \frac{(s^2 + a_1\Omega_1s + \Omega_1^2)(s^2 + a_2\Omega_2s + \Omega_2^2)}{s^4}$$

$$s = j\Omega = j2\pi f_p \quad (= \text{complex frequency})$$

$$a_1 = 1.916; a_2 = 1.241;$$

$$\Omega_1 = 0.09498 \text{ rad/sec}; \Omega_2 = 0.1065 \text{ rad/sec}$$

The variance is, therefore, given by;

$$m_0 = \frac{5}{512} \times \sum_{p=1}^{102} P(p) \cdot S(f_p) \cdot E(f_p)$$

and the significant wave height  $H_s$  is given by:

$$H_s = 4 \cdot \sqrt{m_0}$$

## Appendix B. Analogue Test Records

The instrument includes an analogue chart recorder; in the days before *in-situ* digital processing was possible this was the principal form of output. The paper charts were analysed using the Tucker-Draper statistical method, which gave parameters such as  $H_s$ ,  $T_z$  and a spectral width parameter  $e$ . Charts are still useful as a check on the correct operation, since a skilled observer can often diagnose sensor or circuit malfunctions from an analogue wave trace. It is difficult to tell from the processed output whether all the sensors are working properly. As a check on this, the ship's crew take test records of the output of each sensor on an analogue chart recorder. The test records should consist of four 5 minute sections of chart record made by manually switching out all sensors other than the required one by means of switches on the 4-Channel Detector Unit. Since any switching of the inputs (port and starboard acceleration signals) to the integrators in the SBWR is likely to give rise to a long period damped transient oscillation, the first minute of each section may be unusable for the purposes of the following analysis.

The selected sensor should have been marked on the chart roll and sensors will normally be selected in the order: port accelerometer, port pressure sensor, starboard accelerometer, starboard pressure sensor. The chart speed is nominally 1 mm/sec and an event marker pen at the edge of the chart records a 10 second period square wave time marks. If the pens are not maintained regularly, they may not write properly.

### B.1 Required analysis

Identify the test records on the chart roll and note the date/time on the log sheet. Check that the sections are all of adequate length (e.g. 5 minutes) and if not note this in the log sheet. For each section (sensor), carry out the following operations:

- a) mark out the last 4 minutes of the section (24 square wave timing pen cycles); this should not be subject to noticeable long period ( $\geq 30$  second period) oscillations. A genuine wave record will display oscillations with periods between about 2 and 20 seconds.
- b) draw in a "zero" line by eye. Any long period oscillations may be due to accelerometer faults. If such oscillations occur, the mean "zero" line should be drawn to follow the long period oscillations and the peak-to-peak amplitude of the "zero" line should be noted in the log sheet in the Comments section.
- c) having drawn in the "zero" line, count the number of zero-crossings that the trace makes across the "zero" line in an upward direction (it does not matter which way up the chart is held as the number of upward and downward crossings will only differ by a maximum of 1). Enter this number in the  $N_z$  box on the log sheet.
- d) count the number of crests in the trace (again it does not matter which way up the chart is held as the number of crests and troughs will only differ by a maximum of 1). Enter this number in the  $N_c$  box on the log sheet. Note that some judgement has to be exercised as to what counts as a crest, due to the limited resolution of the pen trace; if in doubt about a feature, count it as a crest.

e) note the overall highest crest and lowest trough of the trace relative to the centre line of the chart paper, measured in mm, as A and C on the log sheet. N.B. do not measure these relative to the "zero" line which you have drawn. The resolution achievable will depend on the trace quality, but a reading to 1 mm is adequate. Note the signs of A and C (+ve above centre line, -ve below centre line) After completing this for all four sections (sensors), finally make any comments about pen problems that you think appropriate. This concludes the analysis.

### LOG SHEET FOR SHIPBORNE WAVE RECORDER

Ship:

Date:

Time:

Port Accelerometer: Record Length OK[ ] SHORT[ ]

Nz [ ] Nc [ ] counts A [ ] C [ ] mm

Port Pressure Sensor: Record Length OK[ ] SHORT[ ]

Nz [ ] Nc [ ] counts A [ ] C [ ] mm

Starboard Accelerometer: Record Length OK[ ] SHORT[ ]

Nz [ ] Nc [ ] counts A [ ] C [ ] mm

Starboard Pressure Sensor: Record Length OK[ ] SHORT[ ]

Nz [ ] Nc [ ] counts A [ ] C [ ] mm

COMMENTS:

The interpretation of the recorded parameters, Nz, Nc, A and C is as follows:

the value of A-C is equal to the peak crest-trough height; the port and starboard accelerometers should give similar heights and, if the ship is pointing into the waves, the port and starboard pressure sensors will also read much the same height, otherwise shadowing due to the ship will result in higher heights on the windward side of the hull. In the absence of any recorded information regarding the ship's heading, only limited inference may be made from the pressure sensor heights. However, a serious fault in a sensor should be obvious.

The value of Nc should always be greater than, or equal to, that of Nz, for a given sensor. Again the values for the port and starboard accelerometers should be broadly similar (given test records of identical length) whereas the values for the pressure sensors may differ appreciably if the ship is, say, lying to. The calculated zero crossing periods (equal to the length of the test record divided by Nz) should normally lie in the range 15 to 5 seconds.

## Appendix C. Examining/Editing the Setup k5

Note that, in the instructions which follow, "enter *xxxxx*" means type in *xxxxx* and then press the Enter key; "press *x*" means simply press the *x* key.

### C.1 Exiting from the Control Program

The setup screens may be examined (and edited, should modifications become necessary in the future) by entering the LabTech Notebook software directly, rather than via the Basic control program. The Basic control program runs automatically when the computer is switched on. Therefore it will first be necessary to escape from the Basic program by pressing *Shift-}* (i.e. Shift and *}* simultaneously). The program may take some time to stop if it is in the middle of running an LTN setup.

### C.2 Running LabTech Notebook

The processor will now be running GWBasic, so that it is necessary to return to DOS by entering *system*. The prompt should now be *C:\NBSBWR\*. Now enter *nb*, whereupon the LTN main menu screen should be displayed. This should include the following options:

SETUP GO ANALYZE CURVE-FIT FFT INSTALL PROGRAM QUIT
---

The menus are hierarchical; to proceed to a lower level menu, either press the key corresponding to its initial letter or highlight the menu, using the grey left/right arrow keys and press *Enter*. To return to a higher level menu, press *Esc*.

When in the main menu, press *S* for SETUP; the menu options should change to:

CHANNELS FILES DISPLAY VERIFY SAVE/RECALL
---

Press *S* for SAVE/RECALL; the menu options should change to:

SAVE RECALL DELETE
--------------------

Press *R* for RECALL; the choice of available setups will then be displayed; this will include the three setups used by the Basic control program, i.e. *k5*, *comp5* and *c5a*. Enter *k5* to load the setup *k5* and then press *Esc* (twice) to return to the menu

CHANNELS FILES DISPLAY VERIFY SAVE/RECALL.
--

Press *C* for CHANNELS; the menu should then change to:

NORMAL HIGH-SPEED
-------------------

Press *N* for NORMAL; the NORMAL DATA ACQUISITION/CONTROL SETUP screen for channel 1 should then appear.

NORMAL DATA ACQUISITION / CONTROL SETUP		
Number of Channels		2
Current Channel(s) [n or n..m]		1
Channel Type	Analog Input	
Channel Name	SBWR 0.1V/metre	
Channel Units	Volts	
Interface Device	1: ACPC-12-16	
Interface Channel Number [0..5]		1
Input Range	±auto V	
Scale Factor	15.000	
Offset Constant	0.000	
Buffer Size	2048	
Number of Iterations	1	
Number of Stages [1..4]	1	
Sampling Rate, Hz	2.000	
Stage Duration, sec. [0.0..1.0E+08]	511.500	
Start/Stop Method	Normal	
Trigger Channel	1	
Trigger Pattern to AND [0..255]	0	
Trigger Pattern to XOR [0..255]	0	
Time Delay, sec. [0.0..1.0E+08]	0.000	
Analog Trigger Value	0.000	
Analog Trigger Polarity	High	
Number of Samples to Save (Pretrigger)	0	

Figure 3 setup k5, part 1

NORMAL DATA ACQUISITION / CONTROL SETUP		
Number of Channels		2
Current Channel(s) [n or n..m]		2
Channel Type	Analog Input	
Channel Name	SBWR 0.1V/metre	
Channel Units	Volts	
Interface Device	1: ACPC-12-16	
Interface Channel Number [0..5]		1
Input Range	±auto V	
Scale Factor	15.000	
Offset Constant	0.000	
Buffer Size	2048	
Number of Iterations	1	
Number of Stages [1..4]	1	
Sampling Rate, Hz	2.000	
Stage Duration, sec. [0.0..1.0E+08]	511.500	
Start/Stop Method	Delay	
Trigger Channel	1	
Trigger Pattern to AND [0..255]	0	
Trigger Pattern to XOR [0..255]	0	
Time Delay, sec. [0.0..1.0E+08]	512.000	
Analog Trigger Value	0.000	
Analog Trigger Polarity	High	
Number of Samples to Save (Pretrigger)	0	

Figure 4 setup k5, part 2

Note the Current Value line at the top left of the screen; this shows the contents of the highlighted box which is to be edited. To view the setup for channel 2, move the highlight box, by means of the grey up/down arrow keys, to the line starting "Current Channel(s)" and then enter 2. The setup for channel 2 should then be displayed.

Note that the channel 2 setup has more lines than can be displayed at one time on the PC screen; it is necessary to scroll by using the grey vertical arrow keys to view all of it.

Return to the setup for channel 1 by moving the highlight box to the line starting Current Channel(s) and enter 1.

The NORMAL DATA ACQUISITION/CONTROL SETUP specifications are displayed in three groups, dealing with the input channel, scaling, sampling.

In the first group, note that the Channel Units are volts, i.e. the values logged are in units of volts. Also note that the Interface Device is [1: ACPC-12-16]; other cards will require different drivers and the installed version of LTN only has a driver for this card apart from [0: DEMO BOARD] (which is a software input simulator).

The second group of settings shows that auto ranging of the analogue signal is to be used, with a scale factor of 15; this effectively scales the input to be in units of metres. The other settings in this group need not concern us.

The third group shows that the sampling rate is 2 Hz and that the Stage Duration is 511.5 seconds. The first sample is initiated at time 0, so that the 1024th is initiated at time 511.5. The Start/stop Method is [Immed(iate).] so that sampling starts as soon as the setup is executed. In contrast, channel 2 has a [Delay] Start/stop and scrolling of the display will show that the delay is 512 seconds.

Now let us examine the file specification screens; these are selected by pressing *Esc* to return to the menu

#### CHANNELS FILES DISPLAY VERIFY SAVE/RECALL.

Press *F* for files; the setup screen for file 1 should then appear. This is indicated by the number in the Current File line.

FILES SETUP	
Number of Files [0..69]	2
Current File [1..2]	1
Data File Name	raw1.prn
Data Storage Mode	ASCII Real
Number of Header Lines [0..4]	4
Header Line 1	LABTECH NOTEBOOK
Header Line 2	raw data1
Header Line 3	The time is \$TIME.
Header Line 4	The date is \$DATE.
No. of Channels in File [0..100]	1
File Column Number	1
Channel Number	1
Channel Name	
Channel Units	
Field Width (ASCII Files)	12
Decimal Places (ASCII Real Files)	8

Figure 5 setup k5, part 3

FILES SETUP	
Number of Files [0..69]	2
Current File [1..2]	2
Data File Name	raw2.prn
Data Storage Mode	ASCII Real
Number of Header Lines [0..4]	4
Header Line 1	LABTECH NOTEBOOK
Header Line 2	raw data2
Header Line 3	The time is \$TIME.
Header Line 4	The date is \$DATE.
No. of Channels in File [0..100]	1
File Column Number	1
Channel Number	2
Channel Name	
Channel Units	
Field Width (ASCII Files)	12
Decimal Places (ASCII Real Files)	8

Figure 6 setup k5, part 4

The setup shows the file name (raw1.prn) and the data storage mode (ASCII Real). In this case the stored data are the measured voltage in decimal ASCII notation, with a format determined by the Field Width and Decimal Places specifications, below.

There then follow details of the file header, which is as follows:

"LABTECH NOTEBOOK" (+ CR LF)

"raw data1" (+ CR LF)

"The time is \$TIME." (+ CR LF)

"The date is \$DATE." (+ CR LF)

- where \$TIME has the format HH:MM:SS.CC and \$DATE has the format MM-DD-YYYY The total length of the header is 88 bytes.

The next four lines deal with the way in which the file is opened and closed - in this case, previous data is to be overwritten. There then follow further data on the format of the file, i.e. single column, field width 12 characters, 8 decimal places. The number of bytes per line of data is equal to the field width (12) plus 3 (space + CR + LF); thus the total length of either the raw1.prn or raw2.prn file is 88 (header) + 1024 x 15 (data) + 1 (EOF) = 15449 bytes.

Thirdly, let us examine the display specification screens; these are selected by pressing *Esc* to return to the menu

CHANNELS FILES DISPLAY VERIFY SAVE/RECALL.
--

Press *D* for display; the following menu should then appear:

WINDOWS TRACES ADJUST
-----------------------

Press *W* for windows and the window setup screen should appear. This specifies the graphics screen windows in which the times series of SBWR signal will be plotted. Channel 1 (the first 1024 samples) is plotted in window 1 and channel 2 (the last 1024 samples) is plotted in window 2.



WINDOW SETUP			
Number of Windows [0..15]		2	
Window Number		1	2
Left Limit, x0 [0.0..1.0]		0.100	0.100
Lower Limit, y0 [0.0..1.0]		0.150	0.600
Right Limit, x1 [0.0..1.0]		0.900	0.900
Upper Limit, y1 [0.0..1.0]		0.500	0.950
Y Axis Title		Ht(seg1)	Ht(seg2)
X Axis Title			
Length of Time (X) Axis in sec.		64.000	64.000
X Tic Start Value		0.000	0.000
X Tic End Value		64.000	64.000
Number of X Tics [0..11]		2	2
Y Tic Start Value		-15.000	-15.000
Y Tic End Value		15.000	15.000
Number of Y Tics [0..11]		3	3
Window Color		Black	Black
Scroll Size [0.0..1.0]		1.000	1.000

Figure 7 setup k5, part 5

The (x0, y0) and (x1, y1) coordinates specify the positions of the bottom left hand corner and top right hand corner of each window, respectively, with (0, 0) being at the bottom left hand corner of the graphics screen and (1, 1) being at the top right hand corner of the graphics screen. It will be apparent that window 1 occupies an area 0.8 wide by 0.35 high below window 2, which has the same dimensions.

The two y-axes are labelled Ht(seg1) and Ht(seg2) but the x-axes are not labelled other than with the start and finish times in seconds. The x-axes have length 64 seconds rather than the full section length of 512 seconds, so as to show the wave profiles clearly. The time series of the SBWR signal is therefore plotted in the bottom window first for the time 0 to 64 seconds; the window then clears completely (achieved by the Scroll Size setting of 1.000) and the x-axis start and finish times change to 64 and 128. The time series is then plotted for a further 64 seconds when the window is cleared again and the start time and finish times change to 128 and 192, etc. After the bottom window has been plotted with the time series from 448 seconds to 512 seconds, the whole process is repeated, using channel 2 (section 2) in the top window.

It will be noted that the x-axes have tics at start and end, whilst the y-axes also have a centre tic and are labelled with the nominal scale of -15 0 +15 (metres).

Now press *Esc* once to return to the menu

#### WINDOWS TRACES ADJUST

and then press *T* for traces. The trace setup should then be displayed. This governs the type of plot (in this case [T vs. Y, a time series plot) and the line type and y-scaling. The chosen line type for both sections of data is a solid line with no symbols. The y-scaling is set by the Y Minimum Displayed Value and Y Maximum Displayed Value. These should be -1.5 and +1.5 (volts), respectively, corresponding to the indicated scale of -15 to +15 (metres). The remainder of the settings are not relevant to this application.

TRACE SETUP		
Number of Traces [0..50]	2	
Trace Number	1	2
Window Number [1..15]	1	2
Line Color	White	White
Line Type	Solid	Solid
Data Point Symbol	None	None
Y Channel Number	1	2
Y Minimum Displayed Value	-15.000	-15.000
Y Maximum Displayed Value	15.000	15.000
Trace Type	T vs. Y	T vs. Y
For Meters Only:		
Number of Decimal Places	3	3
For Type XY Only:		
X Channel Number	1	2
X Minimum Displayed Value	0.000	0.000
X Maximum Displayed Value	10.000	10.000

Figure 8 setup k5, part 6

Now press *Esc* twice to return to the menu:

#### CHANNELS FILES DISPLAY VERIFY SAVE/RECALL

and press *V* for verify; the screen should then show a set of options for the Verify Output. Press *Enter* and the Global Setup Checking screen should be displayed. The setups have been checked for intercompatibility and a brief summary of the overall setup is displayed with the message "Setup OK" if there are no obvious errors. If any changes have been made to the setups this may result in error messages and corrections will be necessary. As mentioned previously, the setups should not be altered without good reason. Any changes will not be saved unless this is done intentionally, so that reloading LTN will allow reinstatement of the previously saved (and hopefully correct) setup files. This does not apply in the case of alterations to the INSTALL OPTIONS and INSTALL HARDWARE setups; any such alterations will be saved automatically when LTN is quitted by pressing *Q* from the main menu (SETUP GO ANALYZE CURVE-FIT FFT INSTALL PROGRAM QUIT).

A point which should be remembered is that, although most of the specifications are edited by highlighting the required value and then entering in a new value, some options must be selected from a submenu which is called by pressing *F1*. The options in this menu are then selected by highlighting the required option using the vertical arrow keys and then pressing *F1* or *Enter* or *Esc*, whereupon the submenu will disappear and the new selection will be specified. This applies to many of the install options and other fixed choices, such as the input interface device in the CHANNELS NORMAL setup

#### Appendix D. Examining/Editing the Setup comp5

To load the setup from the main menu

#### SETUP GO ANALYZE CURVE-FIT FFT INSTALL PROGRAM QUIT

press *S* for Setup, *S* for Save/Recall, *R* for Recall and then enter *comp5*. Press *Esc*, *C* for Channels, *N* for Normal to view the NORMAL DATA ACQUISITION/CONTROL SETUP screen

for channel 1. It will be seen that this time there are 4 channels and that channels 1 and 2 have Channel Type [Replay]. The Data File Names are, respectively, raw1.prn and raw2.prn. Thus, when this setup is executed, data is replayed from the files instead of using an analogue input device as in k5. Note that the data is replayed at 32 times real-time rate, since the Sampling Rate is 64 Hz instead of 2 Hz; this saves time. The stage duration for the 1024 samples is correspondingly shorter at 15.985 seconds ( $1023 \times 1/64 = 15.98438$  seconds). Both channels are replayed simultaneously with Start/Stop Method [Immed.].

NORMAL DATA ACQUISITION / CONTROL SETUP	
Number of Channels	4
Current Channel(s) [n or n..m]	1
Channel Type	Replay
Channel Name	
Waveform File Name	raw1.prn
Waveform File Type	ASCII Real
Number of Columns in File	1
Column Number	1
Buffer Size	1024
Number of Iterations	1
Number of Stages [1..4]	1
Sampling Rate, Hz	64.000
Stage Duration, sec. [0.0..1.0E+08]	15.985
Start/Stop Method	Normal
Trigger Channel	1
Trigger Pattern to AND [0..255]	0
Trigger Pattern to XOR [0..255]	0
Time Delay, sec. [0.0..1.0E+08]	0.000
Analog Trigger Value	0.000
Analog Trigger Polarity	High

Figure 9 setup comp5, part 1

NORMAL DATA ACQUISITION / CONTROL SETUP	
Number of Channels	4
Current Channel(s) [n or n..m]	2
Channel Type	Replay
Channel Name	
Waveform File Name	raw2.prn
Waveform File Type	ASCII Real
Number of Columns in File	1
Column Number	1
Buffer Size	1024
Number of Iterations	1
Number of Stages [1..4]	1
Sampling Rate, Hz	64.000
Stage Duration, sec. [0.0..1.0E+08]	15.985
Start/Stop Method	Normal
Trigger Channel	1
Trigger Pattern to AND [0..255]	0
Trigger Pattern to XOR [0..255]	0
Time Delay, sec. [0.0..1.0E+08]	0.000
Analog Trigger Value	0.000
Analog Trigger Polarity	High

Figure 10 setup comp5, part 2

NORMAL DATA ACQUISITION / CONTROL SETUP		
Number of Channels		4
Current Channel(s) [n or n..m]		3
Channel Type	Calculated	
Channel Name		
Operation	FFT(X)	
X Input Channel		1
Y Input Channel		5
Parameter, r	1024.000	
Scale Factor	1.000	
Offset Constant	0.000	
Buffer Size	2048	
Number of Iterations	1	
Number of Stages [1..4]	1	
Sampling Rate, Hz	6.25E-02	
Stage Duration, sec. [0.0..1.0E+08]	15.985	
Start/Stop Method	Normal	
Trigger Channel	1	
Trigger Pattern to AND [0..255]	0	
Trigger Pattern to XOR [0..255]	0	
Time Delay, sec. [0.0..1.0E+08]	0.000	
Analog Trigger Value	0.000	
Analog Trigger Polarity	High	
Number of Samples to Save (Pretrigger)	0	

Figure 11 setup comp5, part 3

NORMAL DATA ACQUISITION / CONTROL SETUP		
Number of Channels		4
Current Channel(s) [n or n..m]		4
Channel Type	Calculated	
Channel Name		
Operation	FFT(X)	
X Input Channel		2
Y Input Channel		5
Parameter, r	1024.000	
Scale Factor	1.000	
Offset Constant	0.000	
Buffer Size	2048	
Number of Iterations	1	
Number of Stages [1..4]	1	
Sampling Rate, Hz	6.25E-02	
Stage Duration, sec. [0.0..1.0E+08]	15.985	
Start/Stop Method	Normal	
Trigger Channel	1	
Trigger Pattern to AND [0..255]	0	
Trigger Pattern to XOR [0..255]	0	
Time Delay, sec. [0.0..1.0E+08]	0.000	
Analog Trigger Value	0.000	
Analog Trigger Polarity	High	
Number of Samples to Save (Pretrigger)	0	

Figure 12 setup comp5, part 4

Channels 3 and 4 have the Channel Type [Calculated]. The Operation is [FFT(X)] with the X Input Channel set to 1 and 2, respectively. The Y Input Channel is set to 5 in both cases; this results in the FFT operation producing a Power Spectrum with linear scale and Hanning window. The Parameter, r is set to the number of data points used, i.e. 1024 in both cases.

The Sampling Rate is set to 6.25E-02 Hz, this corresponds to 1/(time taken to replay the data), so that the FFT operation is performed just once. The Stage duration is set at 15.985 seconds (the time taken to replay the data). Start/Stop Method is [Immed.].

The resulting spectra from the FFTs performed by channels 3 and 4 are written to the disk file spec.prn. The specification of this can be examined by pressing *Esc* followed by *F* for Files. Once again, the file is in ASCII Real format, but this time it has two columns, corresponding to the two power spectra. The header in this case has a total length of 99 bytes.

FILES SETUP			
Number of Files [0..69]	1		
Current File [1..1]	1		
Data File Name	spec.prn		
Data Storage Mode	ASCII Real		
Number of Header Lines [0..4]	4		
Header Line 1	LABTECH NOTEBOOK		
Header Line 2	indiv. spectrum file		
Header Line 3	The time is \$TIME.		
Header Line 4	The date is \$DATE.		
No. of Channels in File [0..100]	2		
File Column Number	1	2	
Channel Number	3	4	
Channel Name			
Channel Units			
Field Width (ASCII Files)	8	8	
Decimal Places (ASCII Real Files)	5	5	

Figure 13 setup comp5, part 5

The Field Width is 8 characters, with 5 Decimal Places, for each spectral estimate, resulting in 20 bytes per line. Each spectrum consists of 512 estimates, so that the length of the file spec.prn is 99 (header) + 20 x 512 (data) + 1 (EOF), i.e. 10340 bytes.

WINDOW SETUP			
Number of Windows [0..15]	2		
	Window Number	1	2
Left Limit, x0 [0.0..1.0]		0.100	0.100
Lower Limit, y0 [0.0..1.0]		0.125	0.600
Right Limit, x1 [0.0..1.0]		0.900	0.900
Upper Limit, y1 [0.0..1.0]		0.475	0.950
Y Axis Title	Wave Ht.	Wave Ht.	
X Axis Title	sec.	sec.	
Length of Time (X) Axis in sec.	16.000	16.000	
X Tic Start Value	0.000	512.000	
X Tic End Value	512.000	1024.000	
Number of X Tics [0..11]	5	5	
Y Tic Start Value	-15.000	-15.000	
Y Tic End Value	15.000	15.000	
Number of Y Tics [0..11]	5	5	
Window Color	Black	Black	
Scroll Size [0.0..1.0]	1.000	1.000	

Figure 14 setup comp5, part 6

The display WINDOW SETUP has two windows, similar to those used in the setup k5, but in this case the whole of each section of replayed data is displayed in its window. Thus, there is a Length of Time (X) Axis of 16 seconds (the replay stage duration) with an X Tic

Start Value of 0 seconds and an X Tic End Value of 512 seconds, for each window. The y-axes are both labelled with Wave Ht. and have tics at -15, 0 and +15 (metres), as before.

The display TRACE SETUP is the same as for setup k5.

TRACE SETUP			
Number of Traces [0..50]	2		
Trace Number	1	2	
Window Number [1..15]	1	2	
Line Color	White	White	
Line Type	Solid	Solid	
Data Point Symbol	None	None	
Y Channel Number	1	2	
Y Minimum Displayed Value	-15.000	-15.000	
Y Maximum Displayed Value	15.000	15.000	
Trace Type	T vs. Y	T vs. Y	
For Meters Only:			
Number of Decimal Places	3	3	
For Type XY Only:			
X Channel Number	1	2	
X Minimum Displayed Value	0.000	0.000	
X Maximum Displayed Value	10.000	10.000	

Figure 15 setup comp5, part 7

**Appendix E. Examining/Editing the setup c5a**

To load the setup from the main menu

SETUP GO ANALYZE CURVE-FIT FFT INSTALL PROGRAM QUIT
---

press *S* for Setup, *S* for Save/Recall, *R* for Recall and then enter *c5a*. Press *Esc*, *C* for Channels, *N* for Normal to view the NORMAL DATA ACQUISITION/CONTROL SETUP screen for channel 1.

NORMAL DATA ACQUISITION / CONTROL SETUP	
Number of Channels	4
Current Channel(s) [n or n..m]	1
Channel Type	Replay
Channel Name	
Waveform File Name	spec.prn
Waveform File Type	ASCII Real
Number of Columns in File	2
Column Number	1
Buffer Size	2048
Number of Iterations	1
Number of Stages [1..4]	1
Sampling Rate, Hz	64.000
Stage Duration, sec. [0.0..1.0E+08]	7.985
Start/Stop Method	Normal
Trigger Channel	1
Trigger Pattern to AND [0..255]	0
Trigger Pattern to XOR [0..255]	0
Time Delay, sec. [0.0..1.0E+08]	0.000
Analog Trigger Value	0.000
Analog Trigger Polarity	High

Figure 16 setup c5a, part 1

NORMAL DATA ACQUISITION / CONTROL SETUP	
Number of Channels	4
Current Channel(s) [n or n..m]	2
Channel Type	Replay
Channel Name	
Waveform File Name	spec.prn
Waveform File Type	ASCII Real
Number of Columns in File	2
Column Number	2
Buffer Size	2048
Number of Iterations	1
Number of Stages [1..4]	1
Sampling Rate, Hz	64.000
Stage Duration, sec. [0.0..1.0E+08]	7.985
Start/Stop Method	Normal
Trigger Channel	1
Trigger Pattern to AND [0..255]	0
Trigger Pattern to XOR [0..255]	0
Time Delay, sec. [0.0..1.0E+08]	0.000
Analog Trigger Value	0.000
Analog Trigger Polarity	High

Figure 17 setup c5a, part 2

It will be seen that there are, again, 4 channels and that channels 1 and 2 have Channel Type [Replay]. These channels are replayed from, respectively, columns 1 and 2 of the file spec.prm. The Sampling Rate (replay rate) is again 64 Hz and the Stage Duration is 7.985 seconds ( $511/64 = 7.98438$ ).

NORMAL DATA ACQUISITION / CONTROL SETUP		
Number of Channels		4
Current Channel(s) [n or n..m]		3
Channel Type	Calculated	
Channel Name		
Operation	Moving Av	
X Input Channel		1
Y Input Channel		0
Parameter, r	5.000	
Scale Factor	32.000	
Offset Constant	0.000	
Buffer Size	2048	
Number of Iterations	1	
Number of Stages [1..4]	1	
Sampling Rate, Hz	64.000	
Stage Duration, sec. [0.0..1.0E+08]	7.985	
Start/Stop Method	Immed.	
Trigger Channel	1	
Trigger Pattern to AND [0..255]	0	
Trigger Pattern to XOR [0..255]	0	
Time Delay, sec. [0.0..1.0E+08]	0.000	
Analog Trigger Value	0.000	
Analog Trigger Polarity	High	
Number of Samples to Save (Pretrigger)	0	

Figure 18 setup c5a, part 3

NORMAL DATA ACQUISITION / CONTROL SETUP		
Number of Channels		4
Current Channel(s) [n or n..m]		4
Channel Type	Calculated	
Channel Name		
Channel Units	Volts	
Operation	Moving Av	
X Input Channel		2
Y Input Channel		0
Parameter, r	5.000	
Scale Factor	32.000	
Offset Constant	0.000	
Buffer Size	2048	
Number of Iterations	1	
Number of Stages [1..4]	1	
Sampling Rate, Hz	64.000	
Stage Duration, sec. [0.0..1.0E+08]	7.985	
Start/Stop Method	Immed.	
Trigger Channel	1	
Trigger Pattern to AND [0..255]	0	
Trigger Pattern to XOR [0..255]	0	
Time Delay, sec. [0.0..1.0E+08]	0.000	
Analog Trigger Value	0.000	
Analog Trigger Polarity	High	
Number of Samples to Save (Pretrigger)	0	

Figure 19 setup c5a, part 4



Channels 3 and 4 are, once again, "calculated channels", which perform the moving average filtering of the two sets of 512 spectral estimates. The parameter,  $r$ , is set to 5, so that averaging is over groups of 5 estimates. The resulting  $n^{\text{th}}$  output value from channel 3 is given by  $\sum_j x_j/5$ , where  $j = n-4$  to  $n$ . Strictly, this only applies for estimates  $n \geq 5$ .

Note that the Scale Factor is set to 32 in channels 3 and 4. This is done to correct for the effect of the data being replayed for the FFT operation (in setup comp5) at 32 x real-time rate (64 Hz). The FFT power spectral densities from the LTN FFT operation are correct for the replay rate effective bandwidth, i.e. 1/16 Hz, rather than the true bandwidth of 1/512 Hz which applies to the real-time rate.

The smoothed estimates are written to files fft1.prn (channel 3 results) and fft2.prn (channel 4 results). These files have similar headers of total header length 93 bytes.

The format for the smoothed estimates is Field Width 12, Decimal Places 8, giving a total of 15 bytes per estimate. The file lengths are both given by 93 (header) + 512 \* 15 (data) + 1 (EOF) = 7774 bytes.

FILES SETUP	
Number of Files [0..69]	2
Current File [1..2]	1
Data File Name	fft1.prn
Data Storage Mode	ASCII Real
Number of Header Lines [0..4]	4
Header Line 1	LABTECH NOTEBOOK
Header Line 2	spectrum1 file
Header Line 3	The time is \$TIME.
Header Line 4	The date is \$DATE.
No. of Channels in File [0..100]	1
File Column Number	1
Channel Number	3
Channel Name	
Channel Units	
Field Width (ASCII Files)	12
Decimal Places (ASCII Real Files)	8

Figure 20 setup c5a, part 5

FILES SETUP	
Number of Files [0..69]	2
Current File [1..2]	2
Data File Name	fft2.prn
Data Storage Mode	ASCII Real
Number of Header Lines [0..4]	4
Header Line 1	LABTECH NOTEBOOK
Header Line 2	spectrum2 file
Header Line 3	The time is \$TIME.
Header Line 4	The date is \$DATE.
No. of Channels in File [0..100]	1
File Column Number	1
Channel Number	4
Channel Name	
Channel Units	
Field Width (ASCII Files)	12
Decimal Places (ASCII Real Files)	8

Figure 21 setup c5a, part 6

The display WINDOW SETUP has two windows; these display the smoothed spectra for the two sections of data. Thus, there is a The display WINDOW SETUP has two windows,

similar to those used in the setup k5, but in this case the whole of each section of replayed data is displayed in its window. Thus, there is a Length of Time (X) Axis of 8 seconds (the replay stage duration) with an X Tic Start Value of 0 (Hz) and an X Tic End Value of 1 (Hz), for each window. The y-axes are both labelled with Energy and have tics at 0 and 1.

WINDOW SETUP			
Number of Windows [0..15]	2		
	Window Number	1	2
Left Limit, x0 [0.0..1.0]		0.100	0.100
Lower Limit, y0 [0.0..1.0]		0.125	0.600
Right Limit, x1 [0.0..1.0]		0.900	0.900
Upper Limit, y1 [0.0..1.0]		0.475	0.950
Y Axis Title		Energy	Energy
X Axis Title		Freq.	Freq.
Length of Time (X) Axis in sec.		8.000	8.000
X Tic Start Value		0.000	0.000
X Tic End Value		1.000	1.000
Number of X Tics [0..11]		2	2
Y Tic Start Value		0.000	0.000
Y Tic End Value		1.000	1.000
Number of Y Tics [0..11]		2	2
Window Color		Black	Black
Scroll Size [0.0..1.0]		1.000	1.000

Figure 22 setup c5a, part 7

The display TRACE SETUP provides one trace in each window, with the full scale "Energy" set to 10 units.

TRACE SETUP			
Number of Traces [0..50]	2		
	Trace Number	1	2
Window Number [1..15]		1	2
Line Color		White	White
Line Type		Solid	Solid
Data Point Symbol		None	None
Y Channel Number		1	2
Y Minimum Displayed Value		0.000	0.000
Y Maximum Displayed Value		10.000	10.000
Trace Type		T vs. Y	T vs. Y
For Meters Only:			
Number of Decimal Places		3	3
For Type XY Only:			
X Channel Number		1	2
X Minimum Displayed Value		0.000	0.000
X Maximum Displayed Value		10.000	10.000

Figure 23 setup c5a, part 8

## Appendix F. GWBasic Program Listings

### F.1. SBWRCHC.BAS

```

10 ON ERROR GOTO 1690
20 CLS
30 REM Control Program to acquire data from a single analogue input
40 REM using a) LAB NOTEBOOK
50 REM    b) Strawberry Tree ACPC-12-16 Card
60 :
70 REM 2 segments (each of 1024 samples acquired at 2 Hz)
80 REM are stored in disk files raw1.prm and raw2.prm
90 REM using the LAB NOTEBOOK setup "k5"
100 :
110 REM FFT analysis of these 2 sets of data is carried out
120 REM by LAB NOTEBOOK setup "comp5". This stores 2 energy spectra
130 REM in the file spec.prm
140 REM Hanning Window is used. Variance now corrected for this.
150 REM (correction factor for variance is 8/3)
160 :
170 REM Finally, the spectra are reduced to 102 estimates
180 REM - by averaging groups of 5 adjacent estimates -
190 REM and the resulting spectra are written to disk
200 REM in files fjjhhmm and sjjjhhmm, containing 12 runs each
210 :
220 DIM P(512):DIM P1(512) 'arrays for smoothed spectra from LTN files
230 :
240 GOSUB 1790 ' display title page
250 :
260 M$="" 'string for accumulating printer messages
270 :
280 NS%=12 ' number of spectra per file
290 :
300 REM Print date/time in line 14 (restricted print area)
310 PRINT SPC(25);CHR$(186);DATE$,SPC(5);TIME$,CHR$(186);
320 :
330 REM wait for correct starting time, then GOSUB to Julian day routine
340 START$=MID$(TIME$,4,2)
350 IF START$="03" OR START$="23" OR START$="43" THEN F%=0 ELSE F%=1
360 REM 2xIFs req'd since GOSUB in THEN (line 390) returns to next line
370 IF F% THEN GOSUB 1740 ELSE GOSUB 1610
380 IF F% GOTO 310
390 :
400 REM reset to full screen area
410 VIEW PRINT
420 CLS
430 PRINT:PRINT:PRINT
440 PRINT TAB(38)"Wait..."
450 :
460 REM create filenames from julian day and time$
470 F1$="D:\SBWR\F"+JD$+LEFT$(TIME$,2)+MID$(TIME$,4,2)
480 F2$="D:\SBWR\S"+JD$+LEFT$(TIME$,2)+MID$(TIME$,4,2)
490 OPEN F1$ FOR APPEND AS #1
500 OPEN F2$ FOR APPEND AS #2
510 :
520 REM Loop for acq. of NS% pairs of energy spectra

```

```

530 FOR RN% = 1 TO NS%
540   :
550   PRINT:PRINT TAB(28)"Output File Name "F1$
560   PRINT:PRINT TAB(35) "Spectrum "RN%
570   PRINT:PRINT TAB(25)"Loading Data Acquisition Setup"
580   SHELL"copy setup\k5" 'SHELL allows MS-DOS commands
590   IF INKEY$=")" THEN GOSUB 1560
600   CLS
610   PRINT STRING$(8,CHR$(10))
620   PRINT TAB(27)"Running Acquisition Program"
630   PRINT:PRINT
640   COLOR 31:PRINT TAB(38)"Wait":COLOR 15
650   SHELL"go"
660   IF INKEY$=")" THEN GOSUB 1560
670   :
680   PRINT "Loading FFT Processing Setup"
690   SHELL"copy setup\comp5"
700   IF INKEY$=")" THEN GOSUB 1560
710   CLS
720   PRINT STRING$(8,CHR$(10))
730   PRINT TAB(25)"Running FFT Processing Program"
740   PRINT:PRINT
750   COLOR 31:PRINT TAB(38)"Wait":COLOR 15
760   SHELL"go"
770   IF INKEY$=")" THEN GOSUB 1560
780   :
790   PRINT "Loading Averaging Setup"
800   SHELL"copy setup\c5a"
810   IF INKEY$=")" THEN GOSUB 1560
820   CLS
830   PRINT STRING$(8,CHR$(10))
840   PRINT TAB(28)"Running Smoothing Program"
850   PRINT:PRINT
860   COLOR 31:PRINT TAB(38)"Wait":COLOR 15
870   SHELL"go"
880   IF INKEY$=")" THEN GOSUB 1560
890   :
900   PRINT STRING$(8,CHR$(10))
910   PRINT TAB(20)"Copying Spectral Estimates to Files: "
920   PRINT TAB(20)F1$,F2$
930   PRINT:PRINT
940   COLOR 31:PRINT TAB(38)"Wait":COLOR 15
950   OPEN "fit1.prm" FOR INPUT AS #3
960   OPEN "fit2.prm" FOR INPUT AS #4
970   REM Get Headers (H1$-H4$) and raw spectral estimates P(0)-P(511)
980   REM and raw spectral estimates P1(0)-P1(511)
990   INPUT#3,H1$,H2$,H3$,H4$
1000  INPUT#4,H1$,H2$,H3$,H4$
1010  T=0
1020  FOR EST%=0 TO 24:
1025    INPUT#3,P$:P(EST%)=VAL(P$):INPUT#4,P$:P1(EST%)=VAL(P$):NEXT
1030    INPUT#3,P$:P(EST%)=VAL(P$):INPUT#4,P$:P1(EST%)=VAL(P$):
1040    T=T+P(EST%)+P1(EST%):NEXT
1050  :
1060  REM In setup C5A, spectrum is scaled by 32 since FFT was carried out on
1070  REM replayed data with record length of 16 sec. c.f. the original 512 sec.
1080  REM i.e. energy densities were based on widths df=1/16Hz c.f. 1/512Hz
1090  REM Multiply by a further factor of 8/3 to correct for windowing loss
1100  :
1110  REM Write Time and Date of Acq. to disk

```

```

1120 PRINT#1,CHR$(34)H4$CHR$(34)
1130 PRINT#2,CHR$(34)H4$CHR$(34)
1140 PRINT#1,CHR$(34)H3$CHR$(34)
1150 PRINT#2,CHR$(34)H3$CHR$(34)
1160 :
1170 REM Write Averaged Estimates in exponential format.
1180 REM LabTech Notebook setup "comp5a" takes Running Averages over 5
    samples,
1190 REM so P(6)=Average of P(2) to P(6), P(11)=Average of P(7) to P(11), etc.
1200 REM Centre freq of P(6) is 4/512Hz, centre freq of P(11) is 9/512Hz, etc.
1210 :
1220 REM Units m*m/Hz, width of each estimate 5/512Hz
1230 FOR I%=6 TO 511 STEP 5
1240     PRINT#1, USING "+ #####^ ^ ^ ^ ^",2.66667*P(I%)
1250     PRINT#2, USING "+ #####^ ^ ^ ^ ^",2.66667*P1(I%)
1260 NEXT
1270 :
1280 REM 2.6667*T*estimate width (1/512Hz) is total energy for 2 spectra
1290 REM Calculate Hs (H$) and format it (HS$) for printing
1300 H$=STR$(4*SQR(2.66667*T/1024)) 'H$ is sig. wave ht.
1310 IF INSTR(H$,"E") THEN HS$=LEFT$(H$,4)+MID$(H$,INSTR(H$,"E"),4):GOTO
    1340
1320 HS$=LEFT$(H$,INSTR(H$,"")+1)
1330 :
1340 IF LEN(M$)>220 THEN M$=""
1350 M$=M$+CHR$(13)+CHR$(10)+DATE$+" "+LEFT$(TIME$,5)+"Hrs,
    Hs="+HS$+"METRES"
1370 LPRINT M$
1390 M$=""
1400 :
1410 REM wait for correct start time for next record
1420 GOSUB 1790
1430 START$=MID$(TIME$,4,2)
1440 IF START$="03" OR START$="23" OR START$="43" THEN F%=0 ELSE F%=1
1450 PRINT SPC(25);CHR$(186);DATE$,SPC(5);TIME$;CHR$(186);
1460 IF F% THEN GOSUB 1740 ELSE GOTO 1470
1465 IF F% THEN 1430
1470 REM continue with next record
1480 VIEW PRINT:CLS
1490 NEXT
1500 :
1510 REM continue with next file
1520 CLOSE#1:CLOSE#2
1530 GOTO 240
1540 :
1550 REM close down program
1560 CLOSE#1:CLOSE#2:VIEW PRINT:CLS
1570 PRINT "Logging stopped"
1580 END
1590 :
1600 REM Calculate Julian day
1610 MM%=VAL(LEFT$(DATE$,2))
1620 DD%=VAL(MID$(DATE$,4,2))
1630 JD$=STR$(VAL(MID$("000031059090120151181212243273304334",((MM%-
    1)*3)+1,3))+DD%)
1640 JD$=RIGHT$(JD$, (LEN(JD$)-1))
1650 IF LEN(JD$)<3 THEN JD$="0"+JD$:GOTO 1650
1660 RETURN
1670 :
1680 REM Error handling routine
1690 IF ERR=24 OR ERR=25 OR ERR=27 THEN RESUME 1420
1700 IF ERR=57 OR ERR>60 THEN CLS:PRINT "File or I/O Error:","ERN;" at "ERL:END
1710 RESUME NEXT

```

```

1720 :
1730 REM Time display update delay
1740 FOR D%=0 TO 5000:NEXT
1750 PRINT CHR$(13);
1760 RETURN
1770 :
1780 REM Title Screen
1790 VIEW PRINT:CLS
1800 PRINT SPC(7);CHR$(201);STRING$(64,205);CHR$(187)
1810 PRINT SPC(7);" | ----- Acquisition of Spectral Data from SBWR ----- |"
1820 PRINT SPC(7);CHR$(200);STRING$(64,205);CHR$(188)
1830 PRINT:PRINT
1860 PRINT SPC(8);"Waiting for next start time at 03, 23 or 43 minutes past the
hour"
1870 REM setup a window for date/time display on line 9
1880 PRINT SPC(25);CHR$(201);STRING$(29,205);CHR$(187)
1890 PRINT SPC(25);CHR$(186);SPC(6);"Current Date/Time:";SPC(5);CHR$(186)
1900 PRINT:PRINT SPC(25);CHR$(200);STRING$(29,205);CHR$(188)
1910 PRINT
1920 IF M$<>" THEN PRINT TAB(16)"Last Record ";M$ ELSE PRINT TAB(30)"Last Hs
printed out"
1930 VIEW PRINT 9 TO 9
1940 RETURN

```

## F.2. SBWR690.BAS

Differences between this version and SBWRCHC.BAS are listed below:

```

5 REM Version with no disk filing of final spectra (June 1990).
490 REM OPEN F1$ FOR APPEND AS #1
500 REM OPEN F2$ FOR APPEND AS #2
1120 REM PRINT#1,CHR$(34)H4$CHR$(34)
1130 REM PRINT#2,CHR$(34)H4$CHR$(34)
1140 REM PRINT#1,CHR$(34)H3$CHR$(34)
1150 REM PRINT#2,CHR$(34)H3$CHR$(34)
1240 REM PRINT#1, USING "+.#####^ ^ ^ ^";2.66667*P(I%)
1250 REM PRINT#2, USING "+.#####^ ^ ^ ^";2.66667*P1(I%)
1520 REM CLOSE#1:CLOSE#2
1560 REM CLOSE#1:CLOSE#2:VIEW PRINT:CLS
1565 VIEW PRINT:CLS

```

## Appendix G. The GWBasic Control Programs

These programs are nearly identical and are relatively simple; a short description of some of the more important features of each follows:

### G.1. SBWRCHC.BAS

- Line 10 sets up an error handling routine at line 1690 (see below)
- Line 220 dimensions the arrays P(512) and P1(512) into which the smoothed estimates from files fit1.prn and fit2.prn are loaded, respectively

- Line 240 calls a subroutine which displays a title page whilst the program is waiting for the next acquisition start time
- Lines 310-380 are a loop which updates the date/time in the title screen window until the next start time occurs. The subroutine at line 1740 is merely a delay to slow the update rate.

When this occurs, the subroutine at line 1610 is executed; this calculates the Julian day from the real time clock.

- Lines 410-420 restore the full screen area for use
- Lines 470-500 open the files fjjjhhmm and sjjjhhmm in the d:\sbwr directory for appending. These then stay open until 12 spectra have been filed (or until an escape is made from the program)
- Line 530 is the start of the loop which is executed 12 times (for the 12 spectra)
- Lines 550-560 display the output file name d:\sbwr\fjjjhhmm and the number of the spectrum (1 to 12)
- Lines 570-580 recall the setup k5, using a shell to DOS
- Line 590 allows an opportunity to escape if the operator presses SHIFT + ] simultaneously (a shift key code is used to reduce the likelihood of inadvertent operation)
- Lines 600-650 executes LTN go.exe as a subroutine, by a shell to DOS, using the previously-recalled setup k5 (for data acquisition)
- Line 660 allows a further opportunity for escape
- Lines 680-690 recall the setup comp5, using a shell to DOS
- Line 700 allows a further opportunity for escape
- Lines 710-760 executes LTN go.exe, by a shell to DOS, using the previously-recalled setup comp5 (for FFT analysis)
- Line 770 allows a further opportunity for escape
- Lines 790-800 recall the setup c5a, using a shell to DOS
- Line 810 allows a further opportunity for escape
- Lines 820-870 executes LTN go.exe, by a shell to DOS, using the previously-recalled setup c5a (for smoothing)
- Line 880 allows a further opportunity for escape
- Lines 900-1040 transfer the header lines and spectral estimates from LTN files fft1.prn and fft2.prn to the strings H1\$-H4\$ and to the arrays P(512) and P1(512), respectively. Note that H1\$-H4\$ finally hold the header lines from fft2.prn. Also the variable T accumulates the sum of the spectral estimates  $\Sigma[P(n) + P1(n)]$  for  $n = 25$  to  $511$ ; this is used to calculate the significant wave height HS\$. The LTN files are closed.
- Lines 1120-1150 write the time and date headers from the file fft2.prn to the fjjjhhmm and sjjjhhmm files. These have lengths 28 and 27 bytes, respectively, including the CR LFs

- Lines 1230-1260 write every 5th smoothed spectral estimate  $P(n)$  and  $P1(n)$ , from  $n=6$  to  $n=511$ , to the `fjjhhmm` and `sjjhhmm` files, respectively. These estimates (102 in number) are centred on frequencies  $(6-2)/512$  Hz to  $(511-2)/512$  Hz. The estimates are multiplied by  $8/3$  to correct for the loss in variance due to the Hanning data window used in the FFT analysis. Each estimate occupies 11 bytes (+ CRLF)

-Line 1300 calculates the significant wave height,  $H_s$ , from the sum,  $T$ , of the spectral estimates  $P()$  and  $P1()$  between  $n = 25$  and  $n = 511$ , as described in the comment lines 1280-1290

- Lines 1310-1320 format  $H_s$  for printing

- Lines 1340-1390 accumulate the  $H_s$  messages and print them out

- Line 1420 displays the title screen

- Lines 1430-1465 are a loop which updates the date/time in the title screen window until the next start time occurs. The subroutine at line 1740 is merely a delay to slow the update rate.

- Line 1490 is the end of the loop to acquire 12 sets of spectra within the `fjjhhmm` and `sjjhhmm` files

- Line 1520 closes the `fjjhhmm` and `sjjhhmm` files. The file lengths, if complete, are  $12 \times (28 + 27 + 102 \times 13) + 1 = 16573$  bytes

- Line 1530 returns to the start of the process for creating a new pair of `fjjhhmm` and `sjjhhmm` files when the next acquisition start time occurs

- Lines 1610-1660 are a subroutine for calculating the Julian day string JD\$ "jjj" from the real time clock

- Lines 1690-1710 are a subroutine for error handling. Error codes 24 (I/O device timeout),

25 (Printer or Interface hardware error)

27 (Printer out of paper or faulty)

cause the program to continue from line 1420 (wait for next start time with `fjjhhmm` and `sjjhhmm` files open).

Error codes 57 (Fatal Device I/O error)

60+ (various file and disk errors)

cause an error message to be printed out and the program to abort.

- Lines 1740-1760 are a delay for time/date display updating

- Lines 1790-1940 set up the title screen

## G.2. SBWR690.BAS

The version SBWR690.BAS differs from the above in the following details:



- Lines 490-500 are made REMs so that no output disk files of the form fjjhhmm or sjjjhhmm are created
- Lines 1120-1150 are made REMs so that no attempt is made to write headers to output files
- Lines 1240-1250 are made REMs so that no attempt is made to write estimates to output files
- Lines 1520 and 1560 are made REMs so that no attempt is made to close output files

## **Appendix H. DADISP Normalised Batch File**

```
ECHO OFF
: AGAIN
CD \GWBASIC
GWBASIC SCONV
CD \DSP
DADISP2 /C=DCOM.DSP
ECHO PRESS CTRL-C TO END BATCH FILE
ECHO OR TO CONTINUE
PAUSE
GOTO AGAIN
```

## **Appendix I. DaDiSP Command Files**

### **I.1 Command File for Normalised Plots**

```
O SBWR @CR U I SBWR.DSP @CR
P Q W A 10 @CR E @F8 SBWR.1 @CR 10822 @CR SETY(0,-12) @CR
@RT @F8 SBWR.1 @CR 10841 @CR SETY(0,-12) @CR
@RT @F8 SBWR.1 @CR 10901 @CR SETY(0,-12) @CR
@RT @F8 SBWR.1 @CR 10921 @CR SETY(0,-12) @CR
@RT @F8 SBWR.1 @CR 10941 @CR SETY(0,-12) @CR
@RT @F8 SBWR.1 @CR 11001 @CR SETY(0,-12) @CR
@RT @F8 SBWR.1 @CR 11021 @CR SETY(0,-12) @CR
@RT @F8 SBWR.1 @CR 11041 @CR SETY(0,-12) @CR
@RT @F8 SBWR.1 @CR 11101 @CR SETY(0,-12) @CR
@RT @F8 SBWR.1 @CR 11121 @CR SETY(0,-12) @CR
@POP("POP1",40,18,"F5 TO EXIT")
@SUSPEND("@F5")
@ESC Q U D D SBWR.1 @CR Y Q Q C Y E Y
```

### **I.2 Command File for Log Plots**

```
O SBWR @CR U I SBWR.DSP @CR
P Q W A 10 @CR E @F8 SBWR.1 @CR 10822 @CR SETY (0,.02) @CR
@RT @F8 SBWR.1 @CR 10841 @CR SETY (0,.02) @CR
@RT @F8 SBWR.1 @CR 10901 @CR SETY (0,.02) @CR
```

```

@RT @F8 SBWR.1 @CR 10921 @CR SETY (0,.02) @CR
@RT @F8 SBWR.1 @CR 10941 @CR SETY (0,.02) @CR
@RT @F8 SBWR.1 @CR 11001 @CR SETY (0,.02) @CR
@RT @F8 SBWR.1 @CR 11021 @CR SETY (0,.02) @CR
@RT @F8 SBWR.1 @CR 11041 @CR SETY (0,.02) @CR
@RT @F8 SBWR.1 @CR 11101 @CR SETY (0,.02) @CR
@RT @F8 SBWR.1 @CR 11121 @CR SETY (0,.02) @CR
@POP("POP1",40,18,"F5 TO EXIT")
@SUSPEND("@F5")
@ESC Q U D D SBWR.1 @CR Y Q Q C Y E Y

```

### I.3 Command File for Fixed Plots

```

O SBWR @CR U I SBWR.DSP @CR
P Q W A 10 @CR E @F8 SBWR.1 @CR 10822 @CR
@RT @F8 SBWR.1 @CR 10841 @CR
@RT @F8 SBWR.1 @CR 10901 @CR
@RT @F8 SBWR.1 @CR 10921 @CR
@RT @F8 SBWR.1 @CR 10941 @CR
@RT @F8 SBWR.1 @CR 11001 @CR
@RT @F8 SBWR.1 @CR 11021 @CR
@RT @F8 SBWR.1 @CR 11041 @CR
@RT @F8 SBWR.1 @CR 11101 @CR
@RT @F8 SBWR.1 @CR 11121 @CR
@POP("POP1",40,18,"F5 TO EXIT")
@SUSPEND("@F5")
@ESC Q U D D SBWR.1 @CR Y Q Q C Y E Y

```

### I.4 Commands Used In Command File

O	OPEN
SBWR	SBWR LABBOOK
@CR	CARRIAGE RETURN
U	UTILITIES
I	IMPORT
SBWR.DSP	DATA SET
P	PROCEED
Q	QUIT UTILITIES
W	WORKSHEET
A 10	MAKE 10 WINDOWS
E	ENTER WINDOW 1
F8 SBWR.1	LOAD DATA SET SBWR.1
10822	SIGNAL NAME FOR WINDOW 1
@RT	RIGHT ARROW KEY
@POP	POP A TEXT BOX IN REVERSE VIDEO
@SUSPEND	SUSPENDS COMMAND FILE EXECUTION
@ESC	ESCAPE KEY
D	DELETE
D	DATASET SBWR.1
Y	YES
C	CLOSE
E	EXIT

The alpha-numeric characters are interpreted as if they had been typed at the keyboard, therefore the meaning depends on the menu displayed. Letters or words preceded by "@" are either non standard keystrokes or special command file functions.

**Appendix J. Data File for SBWR Data**

```

DATASET SBWR
VERSION 1
NUM_SIGS 10
STORAGE_MODE sequential
DATE 1-01-1991
TIME 08:22:08
NUM_SAMPS 40
SIGNAL 10822, 10841, 10901, 10921, 10941, 11001, 11021, 11041, 11101, 11121
VERT_UNITS Energy
HORZ_UNITS Secs
DATA
+.12076E+01
+.30182E+01
+.49647E+00
+.68949E-01
+.22528E+00
+.66536E+01
+.10978E+02
+.64062E+01
+.50982E+01
+.16021E+02
+.43957E+01
+.28578E+01
-
-
-
-

```

**Appendix K. GWBasic Programs for DADISP Plotting****K.1. GWBASIC Program for Normalised Plots**

```

1 REM
2 REM----- FILENAME C:\GWBASIC\CONV.BAS -----
3 REM
4 REM
5 REM----- define arrays -----
6 REM
10 DIM SBWR$(1040):DIM JD$(12)
20 DIM DAT$(12):DIM TIM$(12):DIM T$(12)
21 REM
22 REM----- enter file pathnames -----
23 REM
30 CLS
40 PRINT:PRINT:PRINT TAB(8)
50 PRINT" Directory path C:\DATA Y/N" :INPUT Y$
60 IF Y$="Y" THEN G$="C:\DATA":GOTO 90
70 IF Y$="Y" THEN G$="C:\DATA":GOTO 90
80 INPUT "Input path\directory name i.e A:\DATA ",G$
90 GG$="DIR "+G$+" /W"
91 REM
92 REM----- display directory using DOS command -----
93 REM
100 SHELL GG$

```

```

101 REM
102 REM----- enter filename with extension -----
103 REM
110 PRINT TAB(8)
120 INPUT "please enter name of file to be plotted ";F$
130 F$=G$+"\ "+F$
140 CLS
141 REM
142 REM----- input data into array -----
143 REM
144 REM----- stripping time and date strings of each record -----
145 REM
150 PRINT:PRINT:PRINT:PRINT
160 PRINT TAB(8)"Sorting data input"
170 OPEN F$ FOR INPUT AS #1
180 FOR I=1 TO 1040
190   INPUT#1,SBWR$(I)
200   IF LEFT$(SBWR$(I),8)="The date" THEN DAT$((I MOD 103))
      =LEFT$(RIGHT$(SBWR$(I),11),10)
210   IF LEFT$(SBWR$(I),8)="The time" THEN TIM$((I MOD 103)-1)
      =LEFT$(RIGHT$(SBWR$(I),12),8)
220   IF LEFT$(SBWR$(I),8)="The time" THEN T$((I MOD 103)-1)
      =LEFT$(TIM$((I MOD 103)-1),2)+MID$(TIM$((I MOD 103)-1),4,2)
230 NEXT I
235 REM
236 REM----- calculate jday number for signal name -----
237 REM
240 FOR I=1 TO 10
250   MM%=VAL(LEFT$(DAT$(I),2))
260   DD%=VAL(MID$(DAT$(I),4,2))
270   JD$(I)=STR$(VAL(MID$("000031059090120151181212243273304334",
      (MM%-1)*3)+1,3))+DD%)
280   T$(I)=JD$(I)+T$(I)
290 NEXT
291 REM
292 REM----- open dadisp file and write header -----
293 REM
300 CLS
310 PRINT:PRINT:PRINT:PRINT
320 PRINT TAB(10) " Writing output files"
330 OPEN "C:\DSP\SBWR.DSP" FOR OUTPUT AS #2
340 PRINT#2, USING"&","DATASET SBWR"
350 PRINT#2, USING"&","VERSION 1"
360 PRINT#2, USING"&","NUM_SIGS 10"
370 PRINT#2, USING"&","STORAGE_MODE sequential"
380 PRINT#2, USING"&","DATE ";DAT$(1)
390 PRINT#2, USING"&","TIME ";TIM$(1)
400 PRINT#2, USING"&","NUM_SAMPS 40"
410 PRINT#2, USING"&","SIGNAL"+T$(1)+","+T$(2)+","+T$(3)+","+T$(4)+","+T$(5)
      +","+T$(6)+","+T$(7)+","+T$(8)+","+T$(9)+","+T$(10)
420 PRINT#2, USING"&","VERT_UNITS Energy"
430 PRINT#2, USING"&","HORZ_UNITS Secs"
440 PRINT#2, USING"&","DATA"
441 REM
442 REM----- output data to dadisp file but only first 40 values -----
443 REM
450 FOR I%=1 TO 1040 STEP 104
460   FOR IA%=2 TO 41
470     PRINT#2, USING"&","SBWR$(I%+IA%)
480   NEXT IA%
490 NEXT I%
493 REM
494 REM----- create dadisp command file -----

```

```

495 REM
500 OPEN "C:\DSPDCOM.DSP" FOR OUTPUT AS #3
510 PRINT#3,USING"&","O SBWR @CR U I SBWR.DSP @CR"
520 PRINT#3,USING"&","P Q W A 10 @CR E @F8 SBWR.1 @CR "+T$(1)+" @CR"
530 PRINT#3,USING"&","@RT @F8 SBWR.1 @CR "+T$(2)+" @CR"
540 PRINT#3,USING"&","@RT @F8 SBWR.1 @CR "+T$(3)+" @CR"
550 PRINT#3,USING"&","@RT @F8 SBWR.1 @CR "+T$(4)+" @CR"
560 PRINT#3,USING"&","@RT @F8 SBWR.1 @CR "+T$(5)+" @CR"
570 PRINT#3,USING"&","@RT @F8 SBWR.1 @CR "+T$(6)+" @CR"
580 PRINT#3,USING"&","@RT @F8 SBWR.1 @CR "+T$(7)+" @CR"
590 PRINT#3,USING"&","@RT @F8 SBWR.1 @CR "+T$(8)+" @CR"
600 PRINT#3,USING"&","@RT @F8 SBWR.1 @CR "+T$(9)+" @CR"
610 PRINT#3,USING"&","@RT @F8 SBWR.1 @CR "+T$(10)+" @CR"
620 PRINT#3,USING"&","@POP(",CHR$(34),"POP1",CHR$(34),"40,18",CHR$(34),"F5 TO
EXIT",CHR$(34);)"
630 PRINT#3,USING"&","@SUSPEND(",CHR$(34),"@F5",CHR$(34);)"
640 PRINT#3,USING"&","@ESC Q U D D SBWR.1 @CR Y Q Q C Y E Y"
650 CLOSE#0
653 REM
654 REM----- exit GWBASIC -----
655 REM
660 SYSTEM

```

## K.2. GWBASIC Program For Logarithmic Plots

```

1 REM
2 REM----- filename C:\GWBASIC\CLOG.BAS -----
3 REM
4 REM
5 REM----- define arrays -----
6 REM
10 DIM SBWR$(1040):DIM JD$(12)
20 DIM DAT$(12):DIM TIM$(12):DIM T$(12)
21 REM
22 REM----- enter file pathname -----
23 REM
30 CLS
40 PRINT:PRINT:PRINT TAB(8)
50 PRINT " Directory path c:\data y/n" :INPUT Y$
60 IF Y$="Y" THEN G$="C:\DATA": GOTO 90
70 IF Y$="y" THEN G$="C:\DATA": GOTO 90
80 INPUT "Input path\directory name i.e A:\DATA ",G$
90 GG$="DIR "+G$+" /W"
91 REM
92 REM----- display directory using DOS command -----
93 REM
100 SHELL GG$
101 REM
102 REM----- enter filename with extension -----
103 REM
110 PRINT TAB(8)
120 INPUT "please enter name of file to be plotted ";F$
130 F$=G$+"\ "+F$
140 CLS
141 REM
142 REM----- input data into array -----
143 REM
144 REM----- stripping time and date strings off each record -----
145 REM
150 PRINT:PRINT:PRINT:PRINT

```

```

160 PRINT TAB(8)" Sorting data input"
170 OPEN F$ FOR INPUT AS #1
180 FOR I=1 TO 1040
190   INPUT#1,SBWR$(I)
200   IF LEFT$(SBWR$(I),8)="The date" THEN DAT$((I MOD 103))
      =LEFT$(RIGHT$(SBWR$(I),11),10)
210   IF LEFT$(SBWR$(I),8)="The time" THEN TIM$((I MOD 103)-1)
      =LEFT$(RIGHT$(SBWR$(I),12),8)
220   IF LEFT$(SBWR$(I),8)="The time" THEN T$((I MOD 103)-1)
      =LEFT$(TIM$((I MOD 103)-1),2)+MID$(TIM$((I MOD 103)-1),4,2)
230 NEXT I
231 REM
232 REM----- calculate jday to generate name for signal -----
233 REM
240 FOR I=1 TO 10
250   MM%=VAL(LEFT$(DAT$(I),2))
260   DD%=VAL(MID$(DAT$(I),4,2))
270   JD$(I)=STR$(VAL(MID$("000031059090120151181212243273304334",
      (MM%-1)*3)+1,3))+DD%)
280   T$(I)=JD$(I)+T$(I)
290 NEXT
295 REM
296 REM----- open dadisp file and write header -----
297 REM
300 CLS
310 PRINT:PRINT:PRINT:PRINT
320 PRINT TAB(10) " Writing output files"
330 OPEN "C:\DSP\SBWR.DSP" FOR OUTPUT AS #2
340 PRINT#2, USING"&","DATASET SBWR"
350 PRINT#2, USING"&","VERSION 1"
360 PRINT#2, USING"&","NUM_SIGS 10"
370 PRINT#2, USING"&","STORAGE_MODE sequential"
380 PRINT#2, USING"&","DATE ",DAT$(1)
390 PRINT#2, USING"&","TIME ",TIM$(1)
400 PRINT#2, USING"&","NUM_SAMPS 40"
410 PRINT#2, USING"&","SIGNAL "+T$(1)+" "+T$(2)+" "+T$(3)+" "+T$(4)+" "+T$(5)
      +" "+T$(6)+" "+T$(7)+" "+T$(8)+" "+T$(9)+" "+T$(10)
420 PRINT#2, USING"&","VERT_UNITS Energy"
430 PRINT#2, USING"&","HORZ_UNITS Secs"
440 PRINT#2, USING"&","DATA"
441 REM
442 REM----- output LOG(data) to file -----
443 REM
444 REM----- only first 40 values and any zero values set to -15 -----
445 REM
450 FOR I%=1 TO 1040 STEP 104
460   FOR IA%=2 TO 41
470     IF SBWR$(I%+IA%)="+.00000E+00" THEN SBWR$(I%+IA%)
        ="-15":GOTO 490
480     SBWR$(I%+IA%)=STR$(LOG(VAL(SBWR$(I%+IA%))))
490     PRINT#2, USING"&","SBWR$(I%+IA%)
500   NEXT IA%
510 NEXT I%
511 REM
512 REM----- create dadisp command file -----
513 REM
520 OPEN "C:\DSP\DCOM.DSP" FOR OUTPUT AS #3
530 PRINT#3,USING"&","O SBWR @CR U I SBWR.DSP @CR"
540 PRINT#3,USING"&","P Q W A 10 @CR E @F8 SBWR.1 @CR "+T$(1)+" @CR
      SETY(0,-12) @CR"
550 PRINT#3,USING"&","@RT @F8 SBWR.1 @CR "+T$(2)+" @CR SETY(0,-12) @CR"
560 PRINT#3,USING"&","@RT @F8 SBWR.1 @CR "+T$(3)+" @CR SETY(0,-12) @CR"
570 PRINT#3,USING"&","@RT @F8 SBWR.1 @CR "+T$(4)+" @CR SETY(0,-12) @CR"

```

```

580 PRINT#3,USING"&","@RT @F8 SBWR.1 @CR "+T$(5)+" @CR SETY(0,-12) @CR"
590 PRINT#3,USING"&","@RT @F8 SBWR.1 @CR "+T$(6)+" @CR SETY(0,-12) @CR"
600 PRINT#3,USING"&","@RT @F8 SBWR.1 @CR "+T$(7)+" @CR SETY(0,-12) @CR"
610 PRINT#3,USING"&","@RT @F8 SBWR.1 @CR "+T$(8)+" @CR SETY(0,-12) @CR"
620 PRINT#3,USING"&","@RT @F8 SBWR.1 @CR "+T$(9)+" @CR SETY(0,-12) @CR"
630 PRINT#3,USING"&","@RT @F8 SBWR.1 @CR "+T$(10)+" @CR SETY(0,-12) @CR"
640 PRINT#3,USING"&","@POP(";CHR$(34);"POPI";CHR$(34);",40,18;CHR$(34);"F5 TO
EXIT";CHR$(34);")"
650 PRINT#3,USING"&","@SUSPEND(";CHR$(34);"@F5";CHR$(34);")"
660 PRINT#3,USING"&","@ESC Q U D D SBWR.1 @CR Y Q Q C Y E Y"
670 CLOSE#0
671 REM
672 REM----- exit GWBASIC -----
673 REM
680 SYSTEM

```

### K.3. GWBASIC Program for Fixed Plots

```

1 REM
2 REM----- filename C:\GWBASIC\CFIX.BAS -----
3 REM
4 REM
5 REM----- define arrays -----
6 REM
10 DIM SBWR$(1040):DIM JD$(12)
20 DIM DAT$(12):DIM TIM$(12):DIM T$(12)
21 REM
22 REM----- enter file pathname -----
23 REM
30 CLS
40 PRINT:PRINT:PRINT TAB(8)
50 PRINT" Directory path C:\DATA y/n" : INPUT Y$
60 IF Y$="Y" THEN G$="C:\DATA":GOTO 90
70 IF Y$="y" THEN G$="C:\DATA":GOTO 90
80 INPUT "Input path\directory name i.e A:\DATA ",G$
90 GG$="DIR "+G$+" /W"
91 REM
92 REM----- display directory using DOS command -----
93 REM
100 SHELL GG$
101 REM
102 REM----- enter filename with extension -----
103 REM
110 PRINT TAB(8)
120 INPUT "please enter name of file to be plotted ";F$
130 F$=G$+"\ "+F$
140 CLS
141 REM
142 REM----- input data into array -----
143 REM
144 REM----- stripping time and date strings of each record -----
145 REM
150 PRINT:PRINT:PRINT:PRINT
160 PRINT TAB(8)"Sorting data input"
170 OPEN F$ FOR INPUT AS #1
180 FOR I=1 TO 1040
190   INPUT#1,SBWR$(I)
200   IF LEFT$(SBWR$(I),8)="The date" THEN DAT$((I MOD 103))
      =LEFT$(RIGHT$(SBWR$(I),11),10)
210   IF LEFT$(SBWR$(I),8)="The time" THEN TIM$((I MOD 103)-1)

```

```

=LEFT$(RIGHT$(SBWR$(I),12),8)
220 IF LEFT$(SBWR$(I),8)="The time" THEN T$((I MOD 103)-1)
=LEFT$(TIM$((I MOD 103)-1),2)+MID$(TIM$((I MOD 103)-1),4,2)
230 NEXT I
231 REM
232 REM----- calculate jday to generate name for signal -----
233 REM
240 FOR I=1 TO 10
250 MM%=VAL(LEFT$(DAT$(I),2))
260 DD%=VAL(MID$(DAT$(I),4,2))
270 JD$(I)=STR$(VAL(MID$("000031059090120151181212243273304334",
((MM%-1)*3)+1,3))+DD%)
280 T$(I)=JD$(I)+T$(I)
290 NEXT
295 REM
296 REM----- open dadisp file and write header -----
297 REM
300 CLS
310 PRINT:PRINT:PRINT:PRINT
320 PRINT TAB(10) " Writing output files"
330 OPEN "C:\DSP\SBWR.DSP" FOR OUTPUT AS #2
340 PRINT#2, USING"&","DATASET SBWR"
350 PRINT#2, USING"&","VERSION 1"
360 PRINT#2, USING"&","NUM SIGS 10"
370 PRINT#2, USING"&","STORAGE_MODE sequential"
380 PRINT#2, USING"&","DATE ";DAT$(1)
390 PRINT#2, USING"&","TIME ";TIM$(1)
400 PRINT#2, USING"&","NUM SAMPS 40"
410 PRINT#2, USING"&","SIGNAL "+T$(1)+" "+T$(2)+" "+T$(3)+" "+T$(4)+" "+T$(5)
+" "+T$(6)+" "+T$(7)+" "+T$(8)+" "+T$(9)+" "+T$(10)
420 PRINT#2, USING"&","VERT_UNITS Energy"
430 PRINT#2, USING"&","HORZ_UNITS Secs"
440 PRINT#2, USING"&","DATA"
441 REM
443 REM----- output first 40 data points to file -----
444 REM
450 FOR I%=1 TO 1040 STEP 104
460 FOR IA%=2 TO 41
470 PRINT#2, USING"&","SBWR$(I%+IA%)
480 NEXT IA%
490 NEXT I%
495 REM
496 REM----- create dadisp command file -----
497 REM
498 REM----- file has commands to fix scales on plots -----
499 REM
500 OPEN "C:\DSPADCOM.DSP" FOR OUTPUT AS #3
510 PRINT#3,USING"&","O SBWR @CR U I SBWR.DSP @CR"
520 PRINT#3,USING"&","P Q W A 10 @CR E @F8 SBWR.1 @CR "+T$(1)+" @CR
SETY(0,.02) @CR"
530 PRINT#3,USING"&","@RT @F8 SBWR.1 @CR "+T$(2)+" @CR SETY(0,.02) @CR"
540 PRINT#3,USING"&","@RT @F8 SBWR.1 @CR "+T$(3)+" @CR SETY(0,.02) @CR"
550 PRINT#3,USING"&","@RT @F8 SBWR.1 @CR "+T$(4)+" @CR SETY(0,.02) @CR"
560 PRINT#3,USING"&","@RT @F8 SBWR.1 @CR "+T$(5)+" @CR SETY(0,.02) @CR"
570 PRINT#3,USING"&","@RT @F8 SBWR.1 @CR "+T$(6)+" @CR SETY(0,.02) @CR"
580 PRINT#3,USING"&","@RT @F8 SBWR.1 @CR "+T$(7)+" @CR SETY(0,.02) @CR"
590 PRINT#3,USING"&","@RT @F8 SBWR.1 @CR "+T$(8)+" @CR SETY(0,.02) @CR"
600 PRINT#3,USING"&","@RT @F8 SBWR.1 @CR "+T$(9)+" @CR SETY(0,.02) @CR"
610 PRINT#3,USING"&","@RT @F8 SBWR.1 @CR "+T$(10)+" @CR SETY(0,.02) @CR"
620 PRINT#3,USING"&","@POP(,CHR$(34),"POP1",CHR$(34),"40,18",CHR$(34),"F5 TO
EXIT",CHR$(34),")"
630 PRINT#3,USING"&","@SUSPEND(,CHR$(34),"@F5",CHR$(34),")"
640 PRINT#3,USING"&","@ESC Q U D D SBWR.1 @CR Y Q Q C Y E Y"

```



```

650 CLOSE#0
651 REM
652 REM----- exit GWBASIC-----
653 REM
660 SYSTEM

```

### Appendix L. Wiring Connections

The port and starboard sensors are connected by cables to a wall-mounted junction box in the Met. Office. Cable then runs from this junction box to the 19" rack containing the SBWR and the NEC PC. These cables both supply power to the sensor interfaces and return the analogue 4-20 mA signals to the electronics unit in the Met. Office.

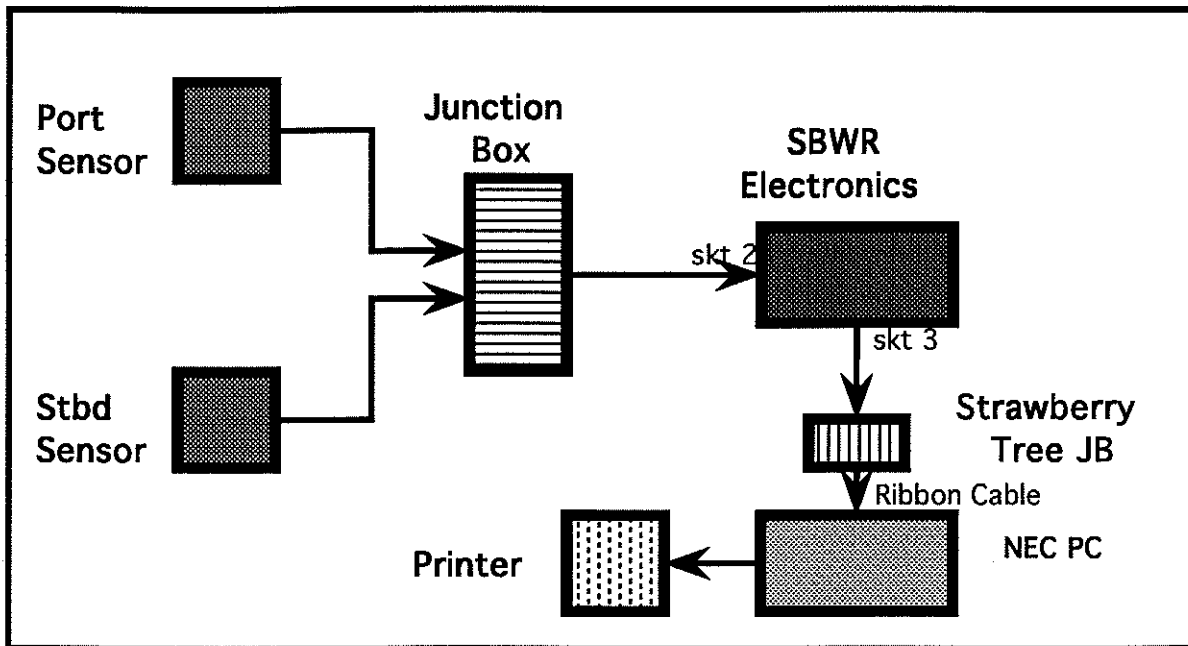


Figure 24 Block Diagram of SBWR Intercabling